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(2)

An Oceanographic and Climatological Atlas of the Chukchi Sea

Carl S. Fontneau

OMNI ANALYSIS
106 Boston Post Road
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SAMUEL F. POWEL, III
Technical Director
U.S. Coast Guard Research and Development Center
Avery Point, Groton, Connecticut 06340-6096

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16. Abstract

This is a reference document of oceanography, meteorology, sea ice distribution, and climatology. It was prepared for use by the U.S. Coast Guard On-Scene Coordinator (OSC) in the event of an oil spill in the Chukchi Sea. The oceanography section contains information for bathymetry, circulation, water temperature and salinity, waves, tides, river discharge, and oil spill transport. The meteorology section includes seasonal weather and storm tracks, storm surges, superstructure icing, and wind chill. Climatology includes graphs and text on temperature, precipitation, wind, visibility, and cloudiness. Ice information includes seasonal formation and drift, concentration, thickness, nearshore ice, and freeze-up and breakup dates.

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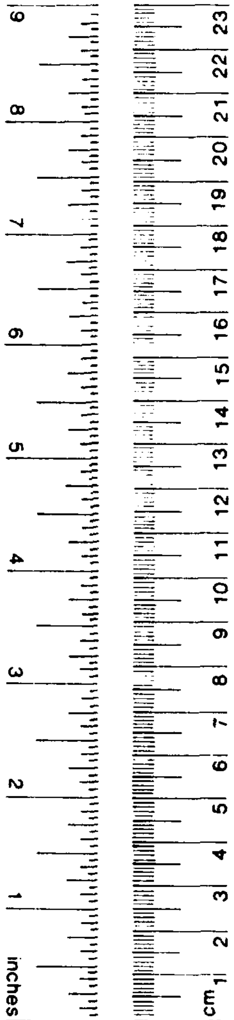
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

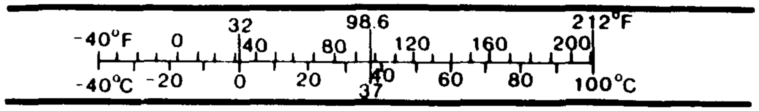
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures. Price $2.25. SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

In the event of an oil spill in the Chukchi Sea or on its shoreline, the U.S. Coast Guard predesignated On-Scene Coordinator (OSC) is responsible for ensuring that timely and adequate containment and removal actions are taken. Responsible parties must take the appropriate clean-up action and the Coast Guard OSC's role will be to monitor these actions. If the response of the spiller is inadequate, or when the responsible party is unknown, the OSC may initiate clean-up actions using federal pollution funds. In either case, the OSC will be operating in a unique, remote, and hostile environment, where clean-up actions are expensive and environmental conditions are very sensitive.

In order to effectively respond to a spill in the Chukchi Sea area, information on the conditions that could affect oil spill behavior and oil cleanup is essential. This environmental atlas has been compiled to provide the OSC with this information for the Chukchi Sea area. This atlas is designed so that the necessary information can be found quickly and is easily understood. It is important to emphasize that an atlas, no matter how complete, cannot replace actual field reconnaissance. It does, however, provide a means by which the user can become familiar with environmental conditions in the area. The atlas also provides reference material for decision making in response needs. It can also help the OSC, who may not have special oceanographic training, obtain the necessary information in a straightforward and visual manner.

The atlas is divided into four sections: Oceanography, Meteorology, Climatology, and Ice. It is designed to answer two questions an OSC responding to an oil spill might ask: (1) into what areas can the spill be expected to drift and how soon and (2) what environmental conditions will personnel be facing at the spill clean-up site? Current weather conditions and the specific geographical location of the spill source would be the atlas entry points for calculating estimated trajectories. This information is located in the oceanography section. Questions regarding expected environmental conditions can be answered from information available from the meteorology, climatology, and ice sections. These sections contain comprehensive graphs, maps, and tables on the means and extremes and frequency of occurrence of environmental conditions and, therefore, operational conditions that response personnel can expect to encounter. Maps and graphs are from up-to-date data compilations available at this time and should remain up to date for quite some time.

OCEANOGRAPHY

INTRODUCTION

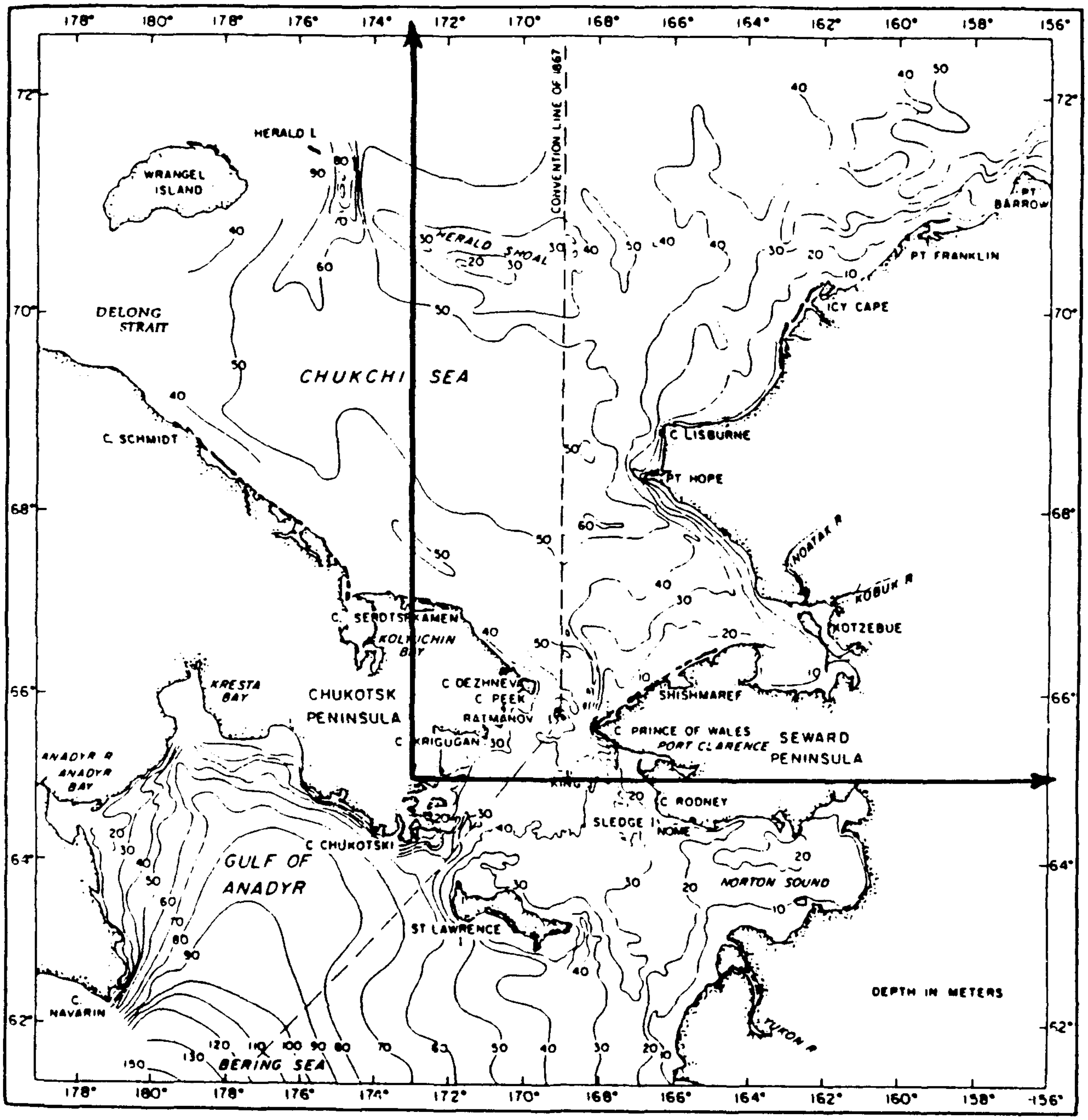
Many variables influence the oceanography of the Chukchi Sea study area extending between 156 and 173°W and 65 to 73°N. The physical characteristics of the Chukchi Sea are unique and complex because this region represents the shallow continental shelf-like connection and transition between two large oceans, the Pacific and the Arctic Oceans.

The contrasting physical oceanographic conditions stem from the fact that, through the Bering Strait, the Chukchi Sea receives the large northward discharge of the North Pacific Ocean. This flow is anomalously warm and of reduced salinity (less than 30 parts per thousand, ppt) causing the Chukchi Sea to become ice-free much earlier in the year than it otherwise would and extending this ice free season later into the fall (Aagaard 1987). There is a marked wind-driven seasonal cycle of water transport through the Bering Strait with summer transport about 50% greater than during the winter. This wind related transport variability and water density layering effects on the Arctic Ocean ultimately influence atmospheric variability and climate. During winter the Chukchi Sea is a source of dense sea water produced through brine rejection during sea ice formation. This dense water gives the thermohaline gradient for mixing of the Arctic Ocean and contributes to wider oceanic circulation. The oceanographic and related climatic extremes of the Chukchi as well as water density, air temperature, daylight, wind, and sea ice dynamics must all be taken in account in the monitoring of transport and cleanup of spilled oil.

BATHYMETRY

The Chukchi Sea occupies the Chukchi Shelf, a shallow segment of the continental shelf of the Arctic Ocean north of the Bering Strait, south of approximately 73°N, bounded on the west by Wrangel Island and the north coast of Siberia, and on the east by the northwest coast of Alaska (figure 1). The bathymetry of the Chukchi Sea is not as well known as that of other coastal areas of Alaska. The major features are a flat central basin about 50m deep, two deep troughs about 60m deep extending into the Arctic Ocean (Herald Canyon near Herald Island and Barrow Canyon northwest of Point Barrow), and a shallow area to 20m at about 71°N and 171°W (Herald Shoal). The northern boundary of the Chukchi Sea is about 700km wide while the 30-50m deep shelf at the Bering Strait is about 60km wide. The study area includes Kotzebue Sound, a large shallow bay where much of the river discharge from the south slopes of the Brooks Range extending east from Point Hope, enters the system through the Kobuk River. Several promontories along the Alaskan coast can influence coastal circulation. These include Point Barrow, Point Franklin, Icy Cape, Point Lay, Cape Lisburne and Point Hope. Figure 2 also shows that bathymetry helps steer the major currents of the Chukchi Sea through the DeLong Strait, through the Herald Canyon, around Herald Shoal, and through Barrow Canyon.

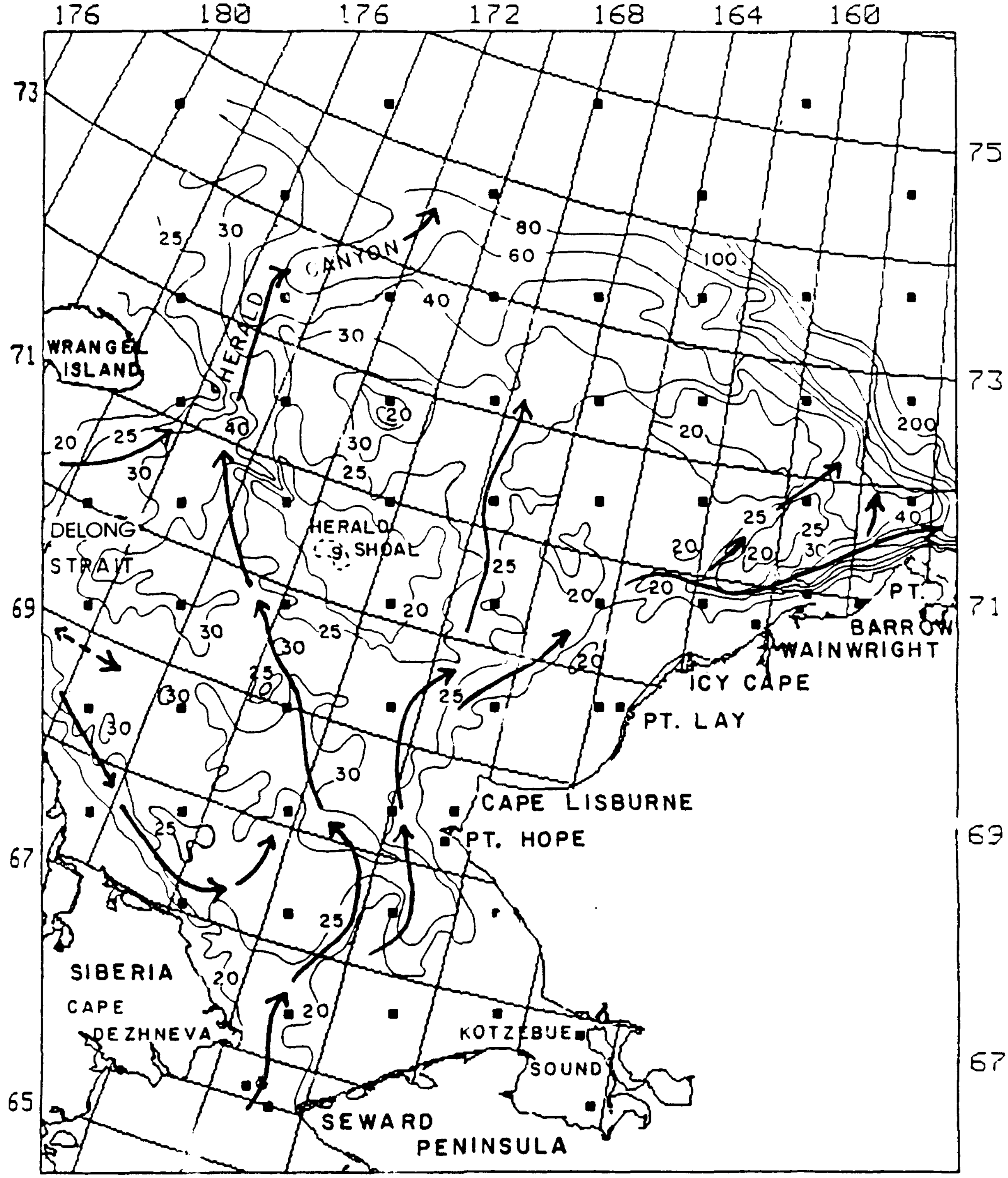
BATHYMETRY



The physiography and bathymetry (depth in meters of the Chukchi Sea study area; bold areas from 65-73°N, from 156-173°W) showing relationship to Norton Sound and Bering Sea areas in the south and the Beaufort Sea area in the northeast corner. After Coachman, Aagaard, and Tripp (1975).

Figure 1

BATHYMETRY AND MAJOR CURRENTS



Bathymetry and major currents in the Chukchi Sea atlas area. (Adapted from Coachman, Aagaard and Tripp [1975] and Paquette and Bourke [1981]. Depths given are in fathoms [1 fathom = 1.83m]). After Stringer and Groves (1987).

Figure 2

CIRCULATION

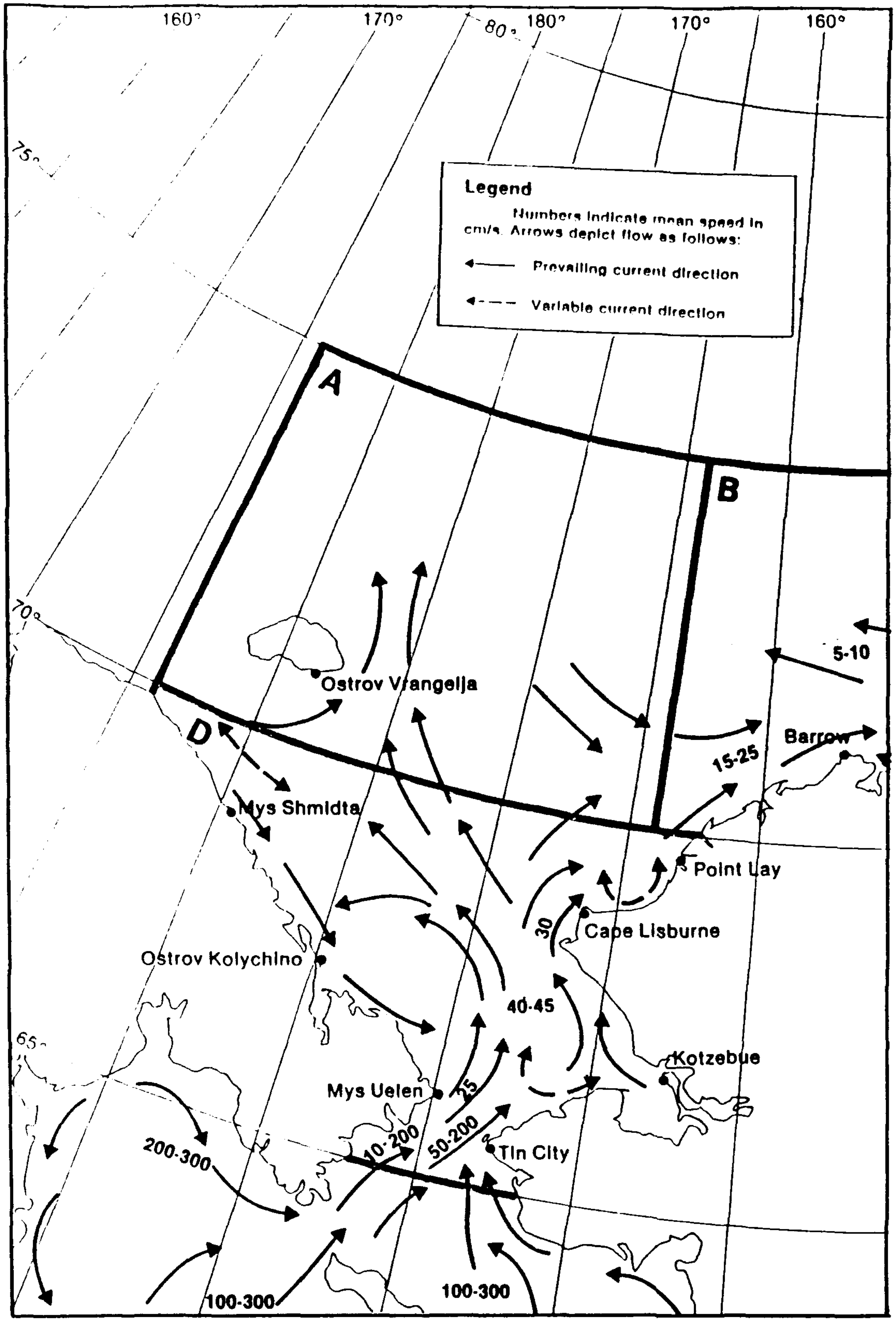
A warm (4-12°C) slow salinity current enters the Chukchi Sea via Bering Strait and flows around Point Barrow to approximately 148°-152°W in the Beaufort Sea. Average rate of flow through the strait is 1.6 x $10^6 m^3/s$. The flow is swiftest on the eastern side of the strait where speeds of up to 200cm/second have been recorded with the flow being strongest during the summer months. In the Chukchi Sea, this current concentrates near the surface and overlies dense bottom water trapped by the shallow depths. It has a fairly uniform velocity which averages 45 cm/s in the summer and 10 cm/s in winter (Arctic Institute of North America 1974). This flow has many meanders and eddies and is slowed somewhat by dominant northeasterly winds. This semipermanent flow is the dominant ibarotropic feature. To the east, in deeper waters, the warm water mass descends to mid-depths. Maximum temperatures are observed in 30- to 50-m depths.

Data from mid-depths indicate a north-flowing current parallel to the shore, and to a marked degree, the bottom contours, with rapid shifts to the south (Wiseman and Rouse 1980). The along-shore component attains speeds as high as 70 cm/s but is typically on the order of 40 cm/s. The current, comprised of Alaskan Coastal Water and Bering Sea Water, hugs the east side of the Chukchi Sea. In the region of Cape Prince of Wales, warm water is present farther to the northeast. The degree of penetration into Kotzebue Sound varies from year to year. Some of the water in Kotzebue Sound is believed to move southwest along the north shore of the Seward Peninsula approximately as far as Shishmaref before joining the general northward flow (Coachman, Aagaard, and Tripp 1975). Near Point Hope and off Cape Lisburne the flow divides. One part flows westward toward Wrangel Island and another part called the Alaskan Coastal Current continues along the Alaskan coast to Point Barrow. Along the coast, data indicate that the current is quite narrow, approximately 37km in places (Bourke and Paquette 1974). North of Point Barrow, the current turns westward with the prevailing Arctic Ocean currents.

From the East Siberian Sea, a colder current (4°C to 6°C) with low salinity enters the Chukchi Sea through DeLong Strait south of Wrangel Island. This other current flows southeast along the Siberian coast and mixes with the warmer shelf waters as it travels. On exceptional occasions, this East Siberian current may continue southward through Bering Strait on the western side, but generally it turns north again before the strait is reached. A strong frontal zone populated with eddies delineates the boundary between the cold current from the East Siberian Sea and the warm current from the Bering Strait. Along the northern part of the Chukchi Sea, currents set to the west with the general Arctic Ocean flow. These current patterns are best developed during the summer as shown in figures 3 and 4.

The warm current pattern can vary considerably due to wind, bathymetry, coastal geomorphology or seasonal ice cover. There is a direct relationship between wind forcing and the transport through the Bering Strait (Aagaard et al. 1985; Spaulding et al. 1988; Mountain 1976). The usual northeastward flow is at a maximum for east-west directed wind and, with change of winds to ENE, the flow reverses occasionally to southwestward (Coachman et al 1975, Aagaard 1981). Flow from the Alaskan Coastal Current through the Barrow Canyon acts as a "drain" for the Chukchi Sea in winter and spring (Garrison and Becker 1976). This current flows generally northeast between Cape Lisburne and Point Barrow with the center of transport about 50-100km off the coast. Near the coast the flow may be northeast. Also it may form recirculation or eddy systems near the major capes due to wind forcing or the influence of coastal geomorphology. A series of three "Carolina Cape" systems (Point Barrow to Point Franklin, Point Franklin to Icy Cape, and Icy Cape to Cape Beaufort) produces divergence of coastal currents along the straight sectors and convergence of currents at the capes.

Sea Surface Currents (cm/s)

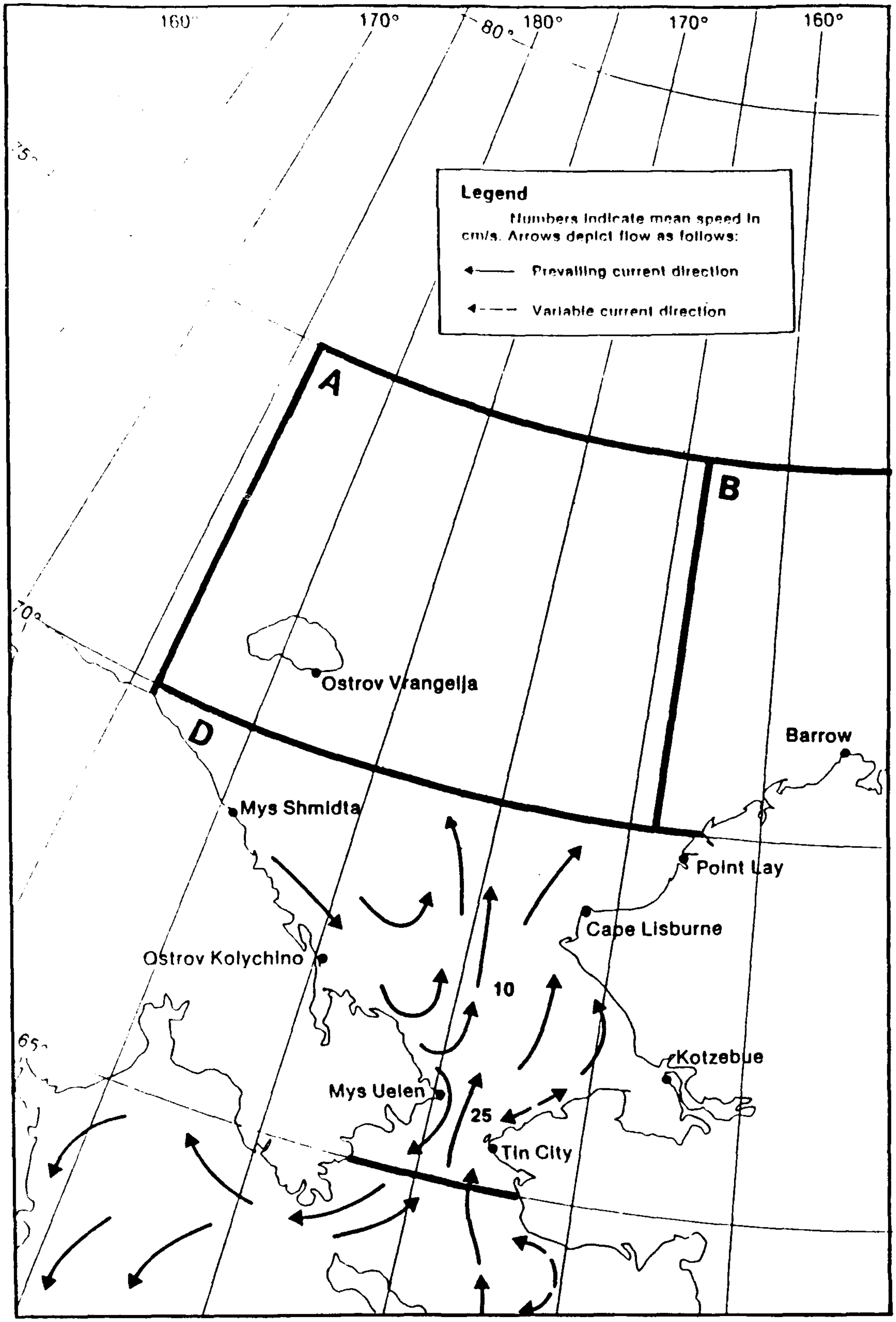


Summer

After Brower et al. 1988

Figure 3

Sea Surface Currents (cm/s)



Winter

After Brower et al. 1988

Figure 4

There is a large anticyclonic eddy between the coast and the warm current (Ingham and Rutland 1972). Within this eddy and the warm current, both surface and deep currents are strongly influenced by wind stress. Velocities lie along the same octant as the wind stress and are similar in magnitude. This implies a strong ibarotropic component in the flow (Ingham and Rutland 1972).

Nearshore current patterns and velocities are very complicated and variable because of coastal configuration, bathymetry, and winds. During southwesterly winds, warm surface waters pile up against the coast. Warm waters are displaced offshore and cooler water upwells along the coast during northeasterly winds. A baroclinic coastal jet may be present. Evidence supporting this current consists of alternation of near-surface current direction and simultaneous coastal setup and setdown, caused by Ekman divergence, in response to changing winds. This results in the transport of warm, low salinity, nearshore water and interaction with the Kasegaluk Lagoon waters. The coastal water mass properties are thus modified. Data suggests that due to strong winds, shallow bathymetry, large coriolis force, and strong stratification, the baroclinic coastal jet probably dominates the coast from Cape Lisburne to Icy Cape during the summer months (Wiseman and Rouse 1980).

Nearshore lagoon water mixes with river runoff and with the coastal waters forced in by storms. Thus coastal water is freshened as well as warmed by solar radiation. Water within the lagoon becomes well mixed due to wind changes which weaken the vertical stratification.

Water movement from the Bering Strait to Cape Lisburne takes 10-15 days in the summer (Arctic Institute of North America 1974). Other known velocities are listed for the Alaskan Coastal Water. It moves north at 50-200 cm/s on the east coast of the Bering Strait (AEIDC 1975; Arctic Institute of North America 1974; Henkins and Kaplin 1966); 0-50 cm/s on the Siberian side (AEIDC 1975); 25 cm/s near Diomede Island (AEIDC 1974); 50 cm/s near Cape Thompson (AEIDC 1974); 15-25 cm/s for currents parallel to the coast at the surface (0-10m) in the summer (Coachman et al. 1976); and approximately 30 cm/s near Icy Cape (Coachman et al. 1976).

Tidal currents are rotary and very weak in the Chukchi. They vary from 0.25 to 0.85 cm/s depending on the location and tidal stage. Nearshore the tidal currents appear to be small, on the order of 1cm/s (Wiseman et al. 1973). Kotzebue Sound currents are mostly tide- and wind-induced. Velocities through and within the sound are very slow, averaging less than 0.1 cm/s.

WATER MASS PROPERTIES

Temperature and salinity are the two properties commonly monitored to establish source and fate of different water masses. There are two basic water mass types plus some modified types in the Chukchi Sea (Aagaard 1987). The higher salinity water mass consists of Bering Sea Water (BSW) formed from the combination of Bering Shelf and Anadyr Water in the northernmost Bering Sea. In summer, the BSW is relatively warm (1-7°C) and has a salinity range of 32.2-33.8‰. BSW enters the Chukchi Sea as the western part of the northward flow passing through the Bering Strait (figure 3). The currents transporting BSW follow the shallow bottom topography, initially moving toward Kotzebue Sound. By Point Hope, these currents move the BSW northwestward across the central Chukchi Sea. Around Herald Canyon, currents transporting BSW from northward and enter the Arctic Ocean.

The second water mass carried northward through the Bering Strait is the Alaskan Coastal Water (ACW) which represents the lower-salinity fraction of the flow. In summer the ACW is usually somewhat warmer (2-10°C), characterized by a reduced and wider range of salinity (usually less than 31‰) compared to the BSW. The ACW remains distinct from the more saline BSW to the west with only limited lateral mixing and with possible further reductions in salinity through intrusions of Kotzebue Sound water as it flows northward to about the Point Hope area. Near this latitude, the two water masses diverge and the ACW is conducted northeastward (figure 2). During the northeastward transit along the northwestern Alaskan coast, the ACW meets a third water mass of the Chukchi Sea, the resident Chukchi Sea Water (RCW). The RCW represents either the varied water remaining on the Chukchi Shelf from the previous winter, when the water columns are homogeneous vertically, or incursions of upper Arctic Ocean water. The RCW has near freezing temperatures and salinity equal to or greater than the ACW. This RCW usually is flushed from the eastern Chukchi Sea as far north as Cape Lisburne by mid-to-late summer.

At the western most border of the study area along the coast of Siberia, another water mass, the East Siberian Coastal Water, may intrude. This water is very cold (less than 1°C) and has salinity less than 30.5‰ resulting from discharge from Siberian river systems.

In addition to mixing of the various water masses and river discharge near Alaskan and Siberian coasts, seasonal ice production and melting greatly modifies water mass properties through changes in salinity and temperature near the surface. Sharp temperature and salinity fronts at the edge of a retreating ice pack are formed when ice melts due to warm surface water intrusion from the south (Paquette and Bourke 1981). Mid summer surface and bottom salinity and temperature isolines are shown in figures 5 and 6. In August, mean surface temperatures are less than -1.1°C near the ice, 2.2°C in the East Siberian Sea, and 10°C in Kotzebue Sound. Cooling begins in late September. The water column remains isothermal from December to May. The temperature structure is modified in the eastern part of the Chukchi Sea as warmer BSW moves into the region in June.

During the summer, mean surface salinity of the Chukchi Sea varies from less than 26‰ in areas of fresh water intrusion to 31‰ in the central tongue of the region. Melting sea ice or river discharge add freshened water at the surface resulting in surface salinity values down to less than 10‰ near the ice.

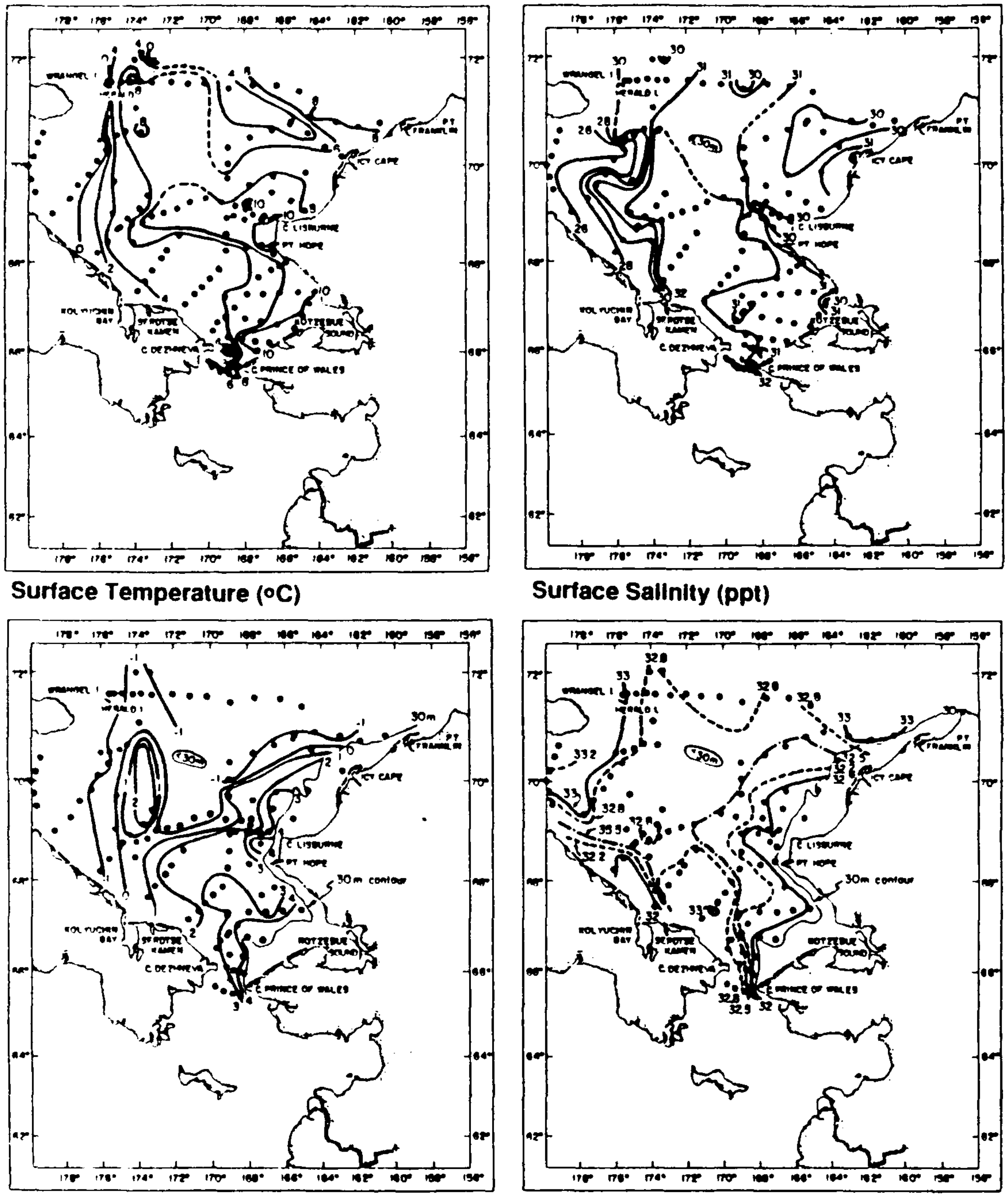
Water density, a critical factor in the transport and cleanup of spilled oil, is a function of temperature, salinity, and pressure. It will impact the buoyancy, trajectory, and fate of spilled oil in the Chukchi Sea. At high latitudes (arctic and subartic waters) salinity is the major component determining sea water density, which is represented by the function (sigma-t). At the sea surface, the average density is about 1.025 gm/cm^3. It is necessary to know the density to at least five decimal places, and all numerical values of seawater density (ρ) begin with 1.0. A custom of representing the density in an abbreviated form is given by

$$\text{sigma-t} = (\rho - 1) \times 10^3.$$

So a seawater density of 1.02478 has a sigma-t of 24.78. Seasonal vertical and horizontal fluxes and advection of water masses influence the circulation dynamics, particularly during times of low wind and ice cover.

The distribution and variation of density in the Chukchi Sea region are controlled mostly by the highly variable salinity. In winter, density is at a maximum of 25 sigma-t units. In summer, surface density varies from 21 to 24.5 sigma-t units. Density values in extreme cases near melting ice can be less than 5 sigma-t units. During the summer season, there can be sharp density gradients between extremely light surface water and denser bottom waters.

Midsummer Temperature and Salinity



Surface Temperature (°C)

Surface Salinity (ppt)

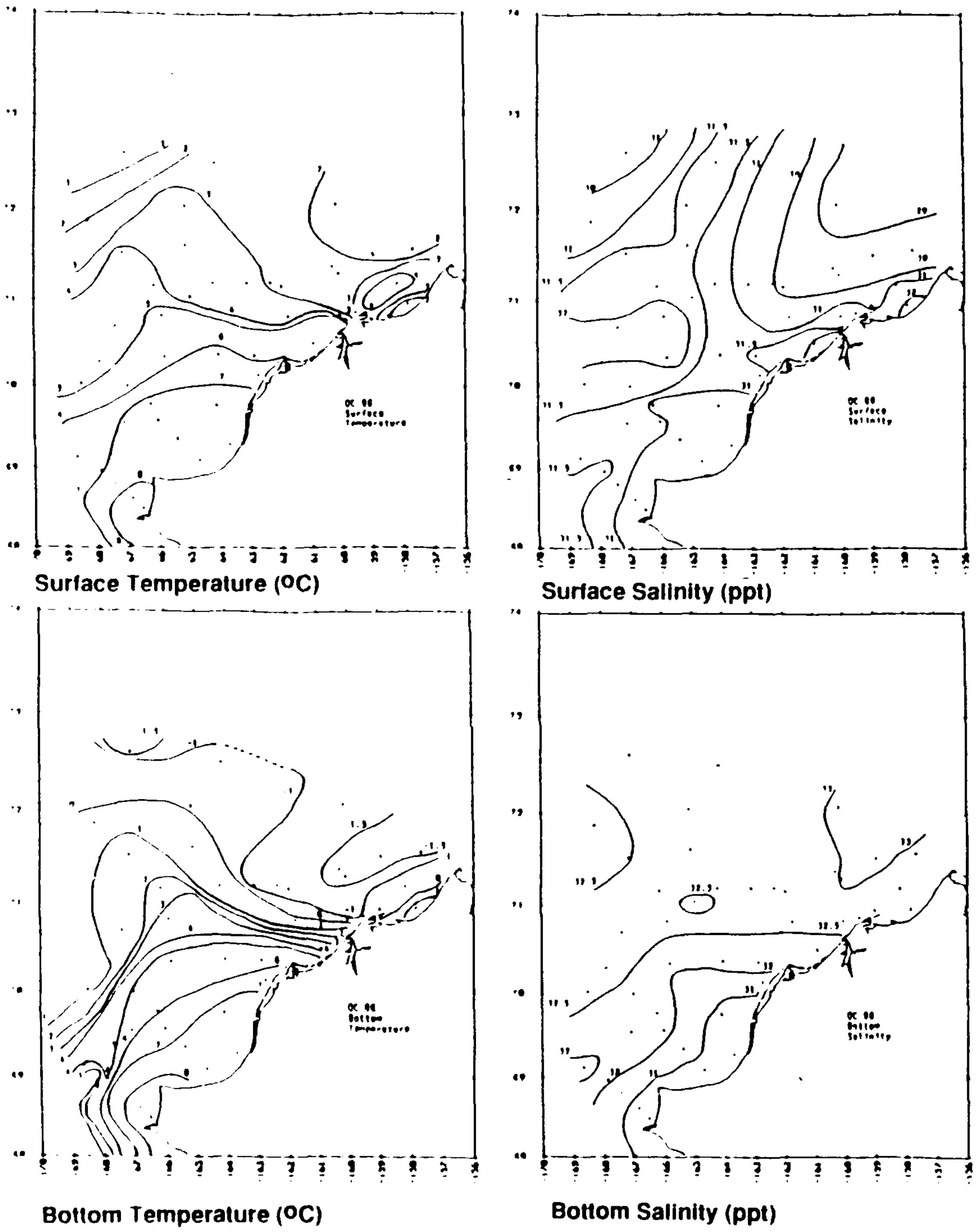
Bottom Temperature (°C)

Bottom Salinity (ppt)

Midsummer surface (0-10m) average temperature (°C) and salinity (ppt) and bottom average temperature and salinity. After Coachman et al. 1975.

Figure 5

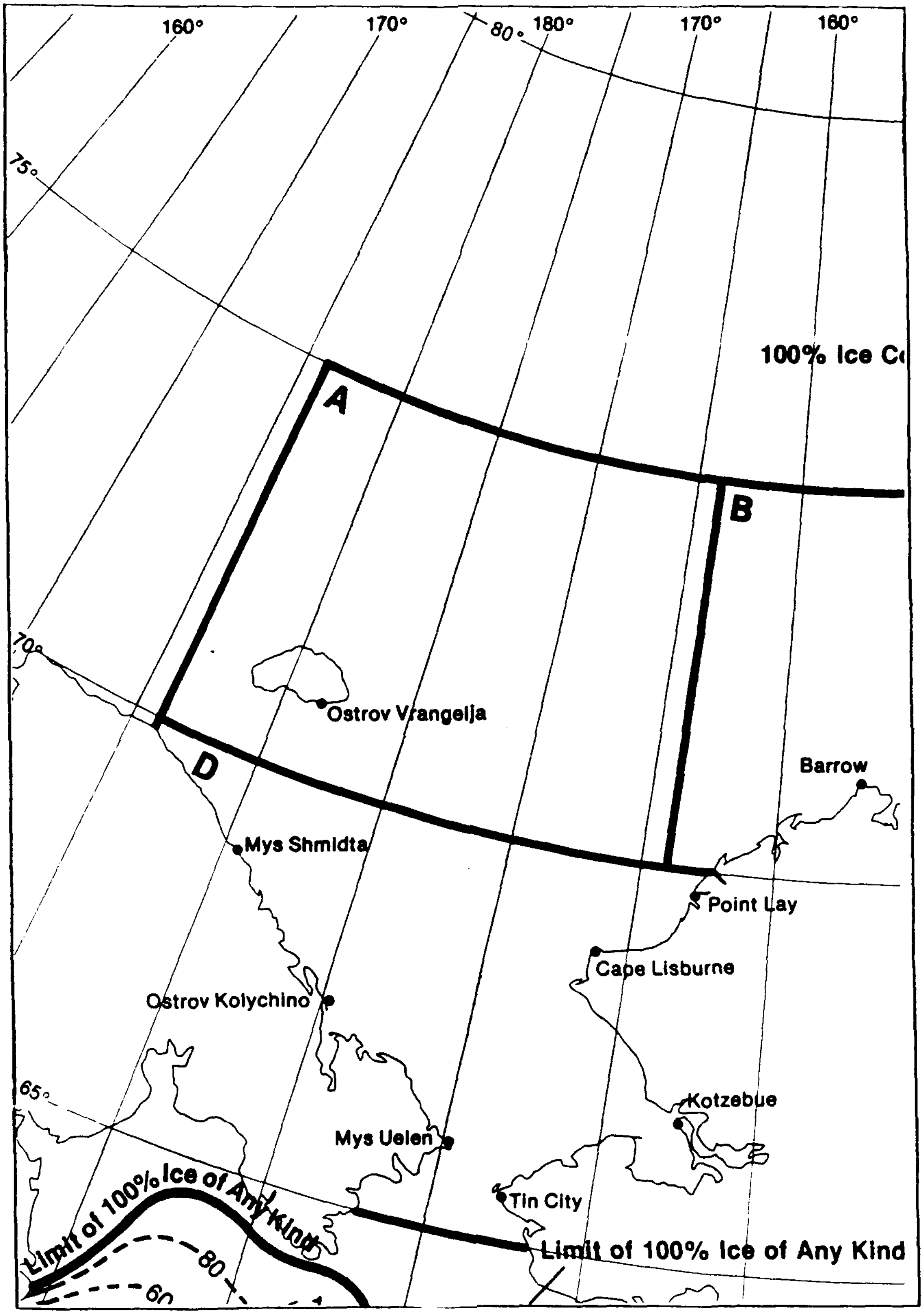
August/September Temperatures and Salinity



Recent surface and bottom temperatures and salinities from August/September (After Johnson 1988).

Figure 6

Sea Surface Temperature Means



January

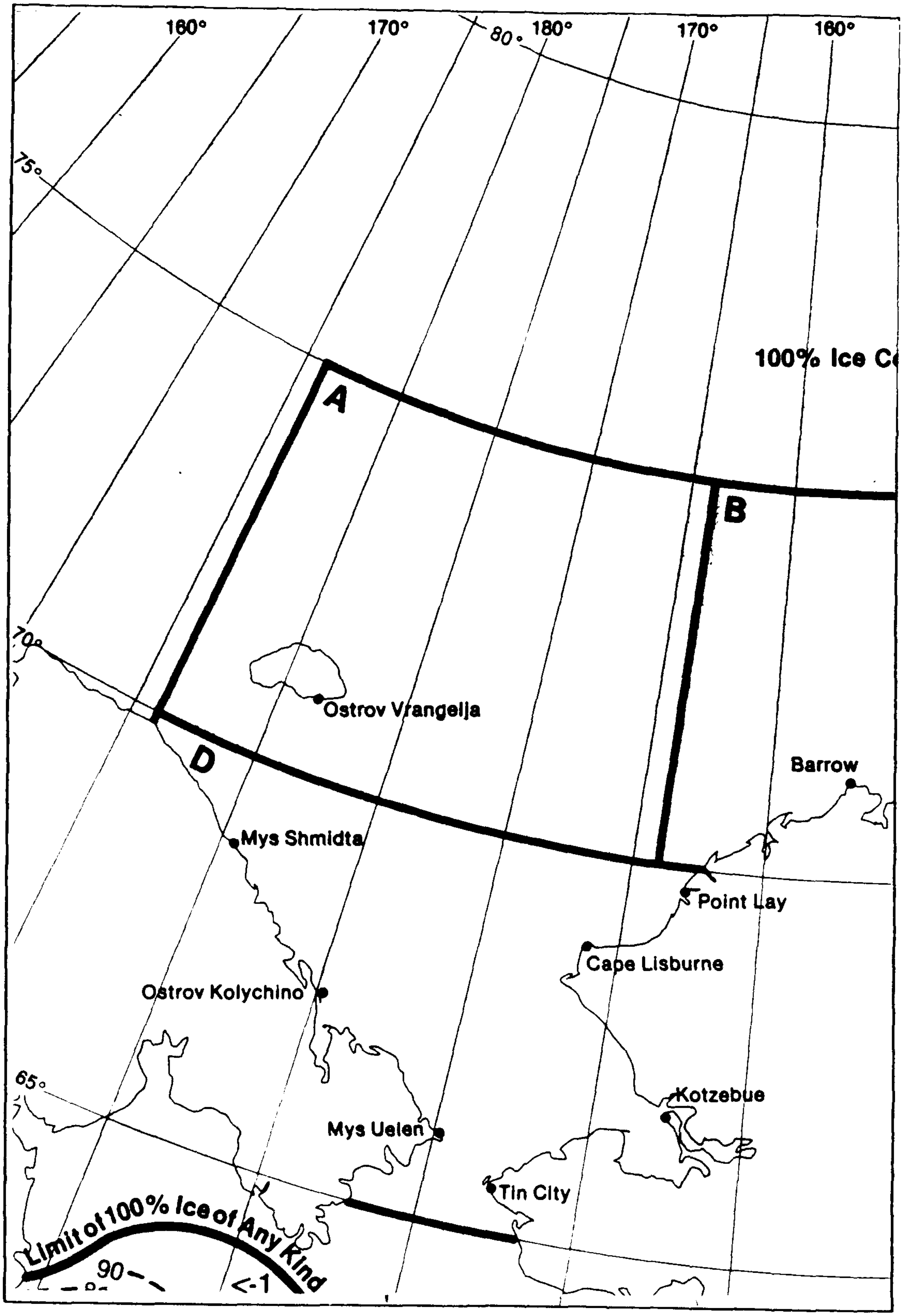
After Brower et al. 1988

Legend

——— Sea Surface Temperature °C
— — — % Frequency of Ice of Any Kind

Figure 7a

Sea Surface Temperature Means



After Brower et al. 1988

February

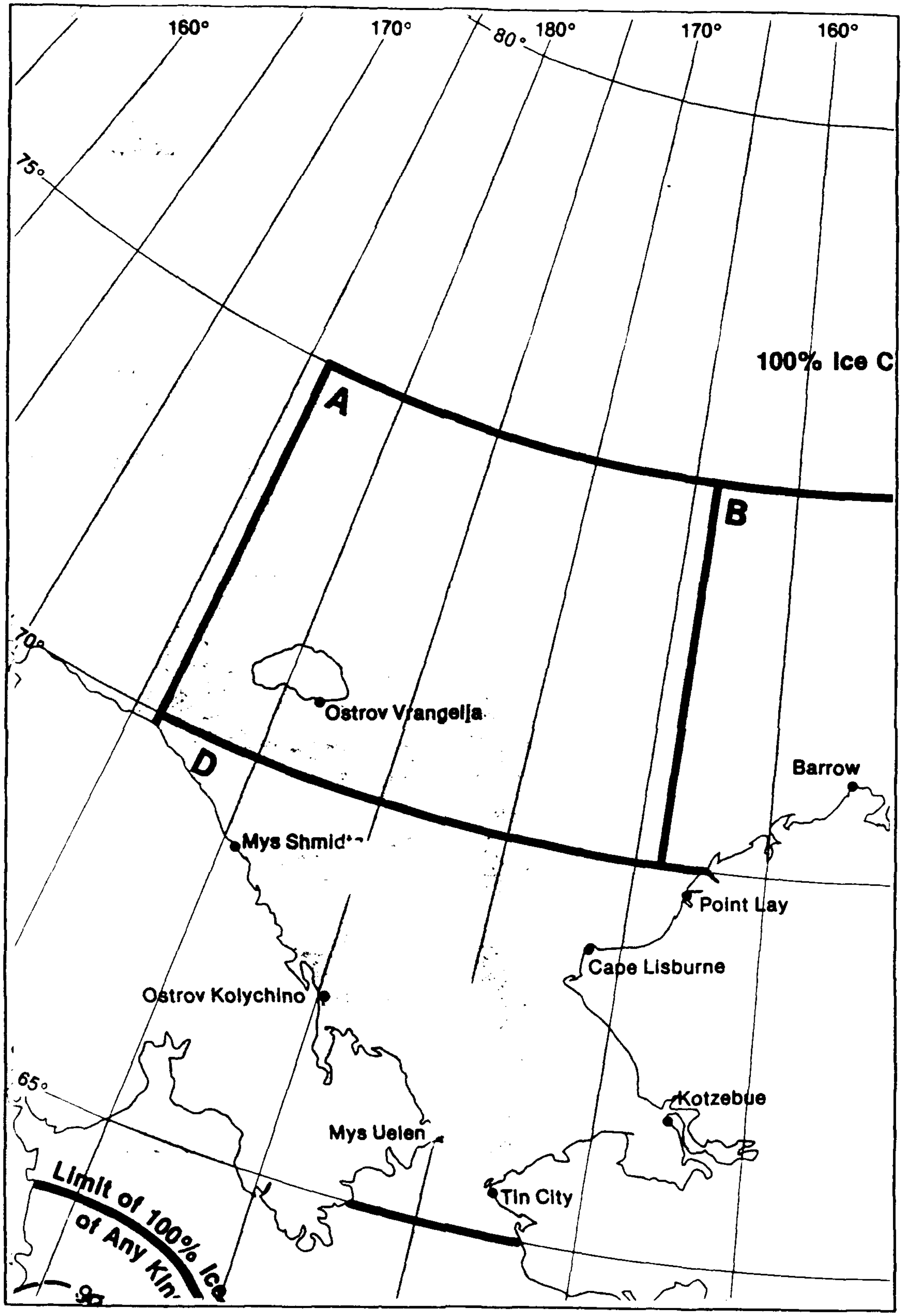
Legend

——— Sea Surface Temperature °C

— — — % Frequency of Ice of Any Kind

Figure 7b

Sea Surface Temperature Means



After Brower et al. 1988

March

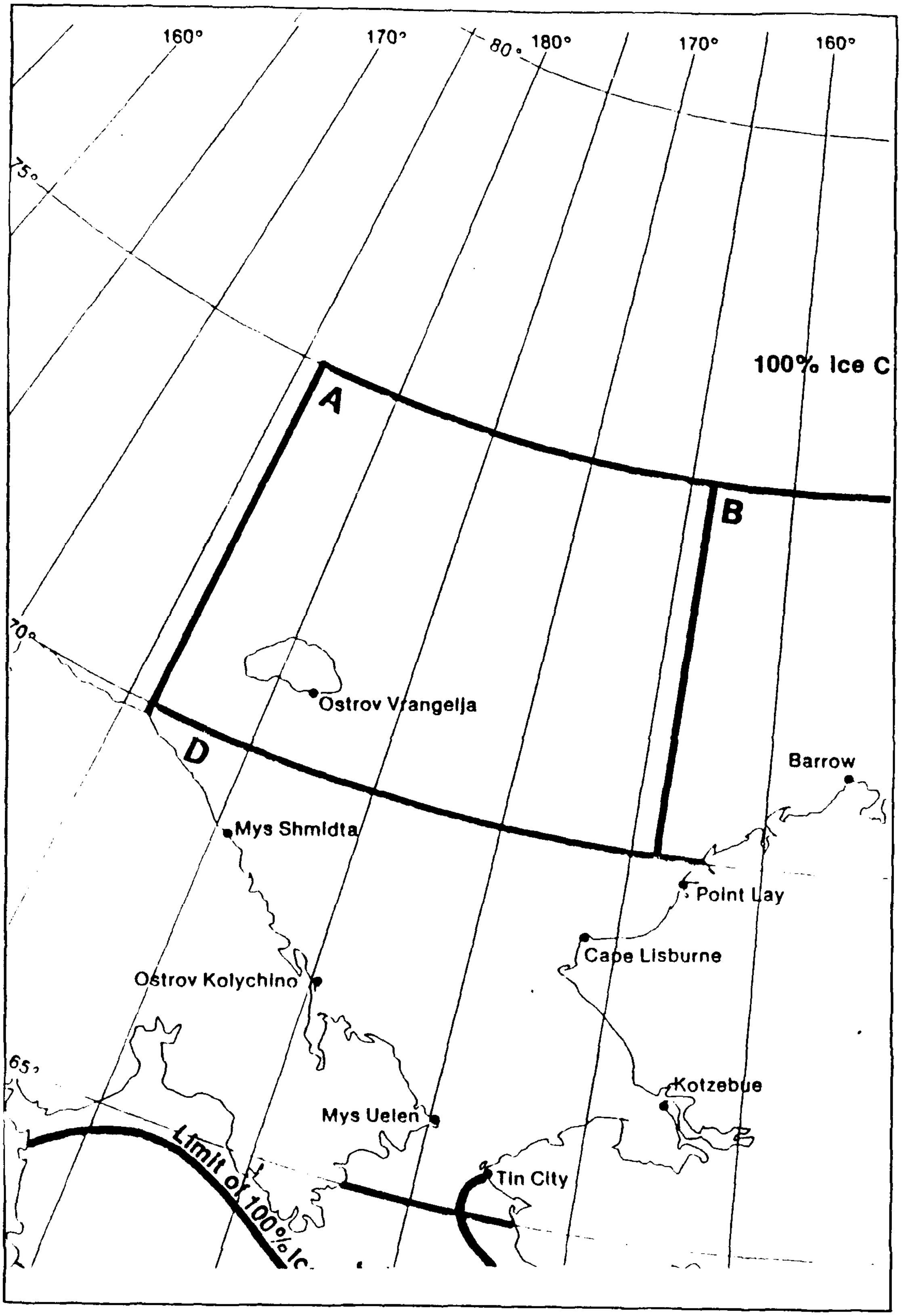
Legend

Sea Surface Temperature °C

% Frequency of Ice of Any Kind

Figure 7c

Sea Surface Temperature Means



After Brower et al. 1988

April

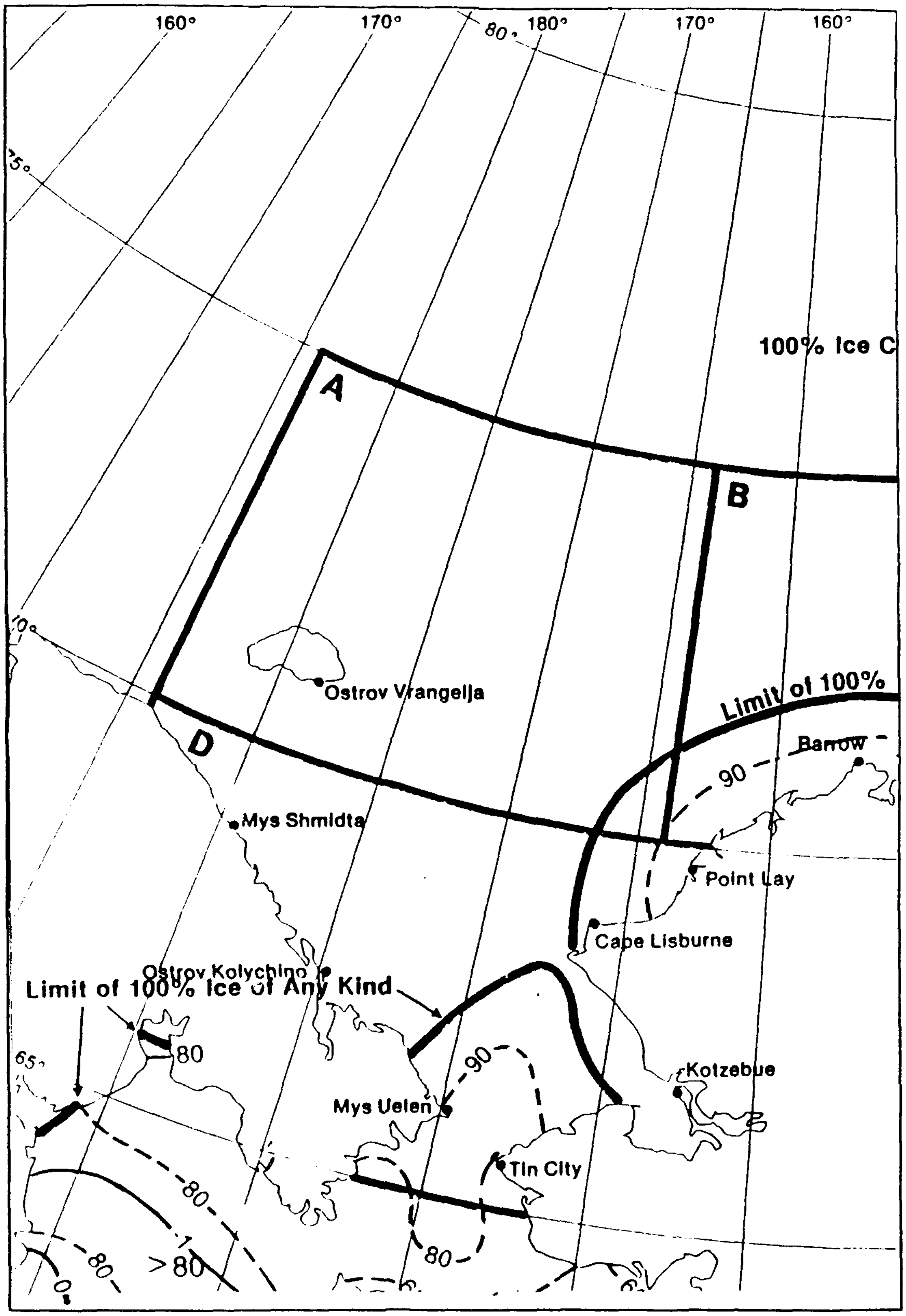
Legend

——— Sea Surface Temperature °C

– – – % Frequency of Ice of Any Kind

Figure 7d

Sea Surface Temperature Means



After Brower et al. 1988

May

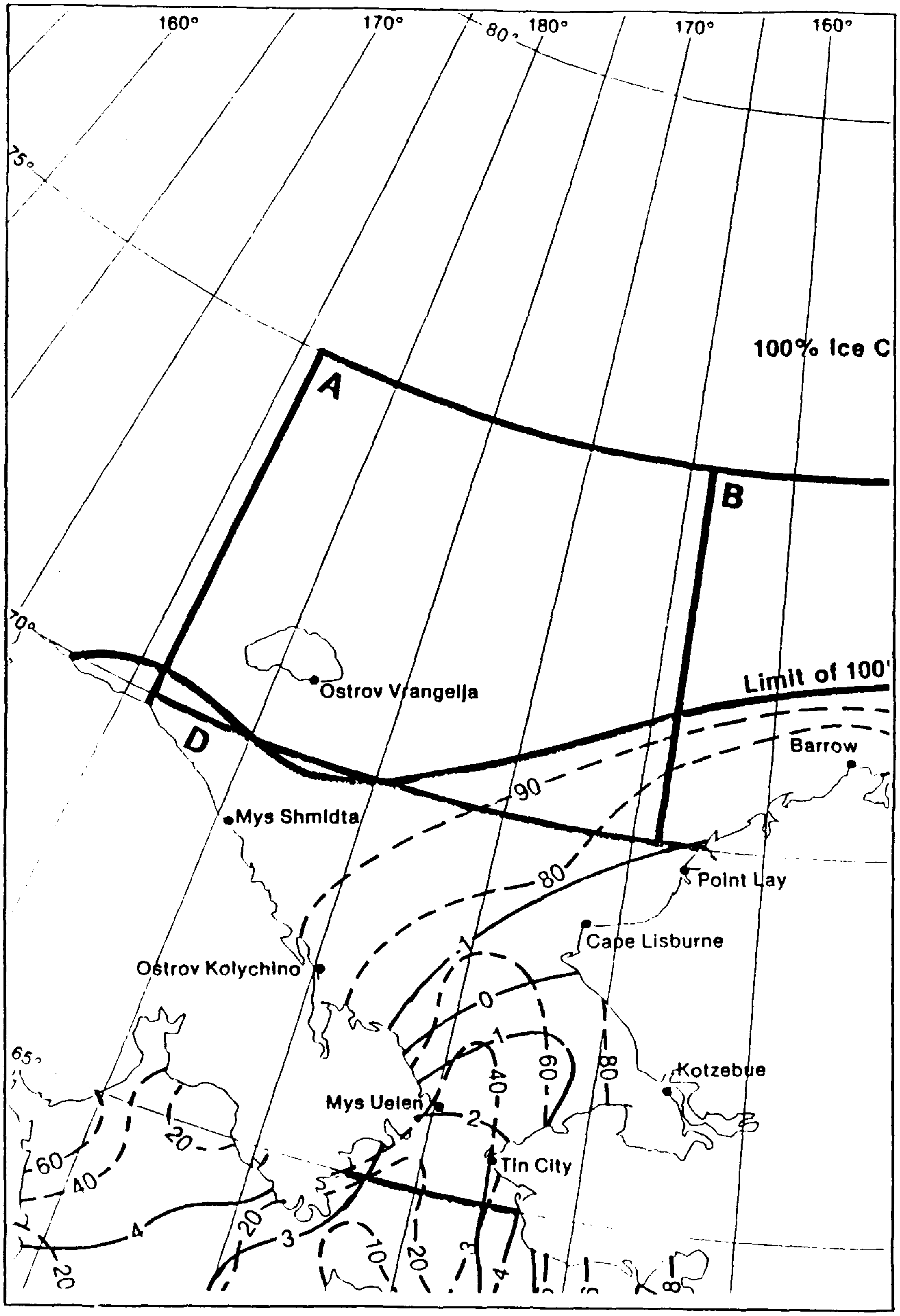
Legend

——— Sea Surface Temperature °C

— — — % Frequency of Ice of Any Kind

Figure 7e

Sea Surface Temperature Means



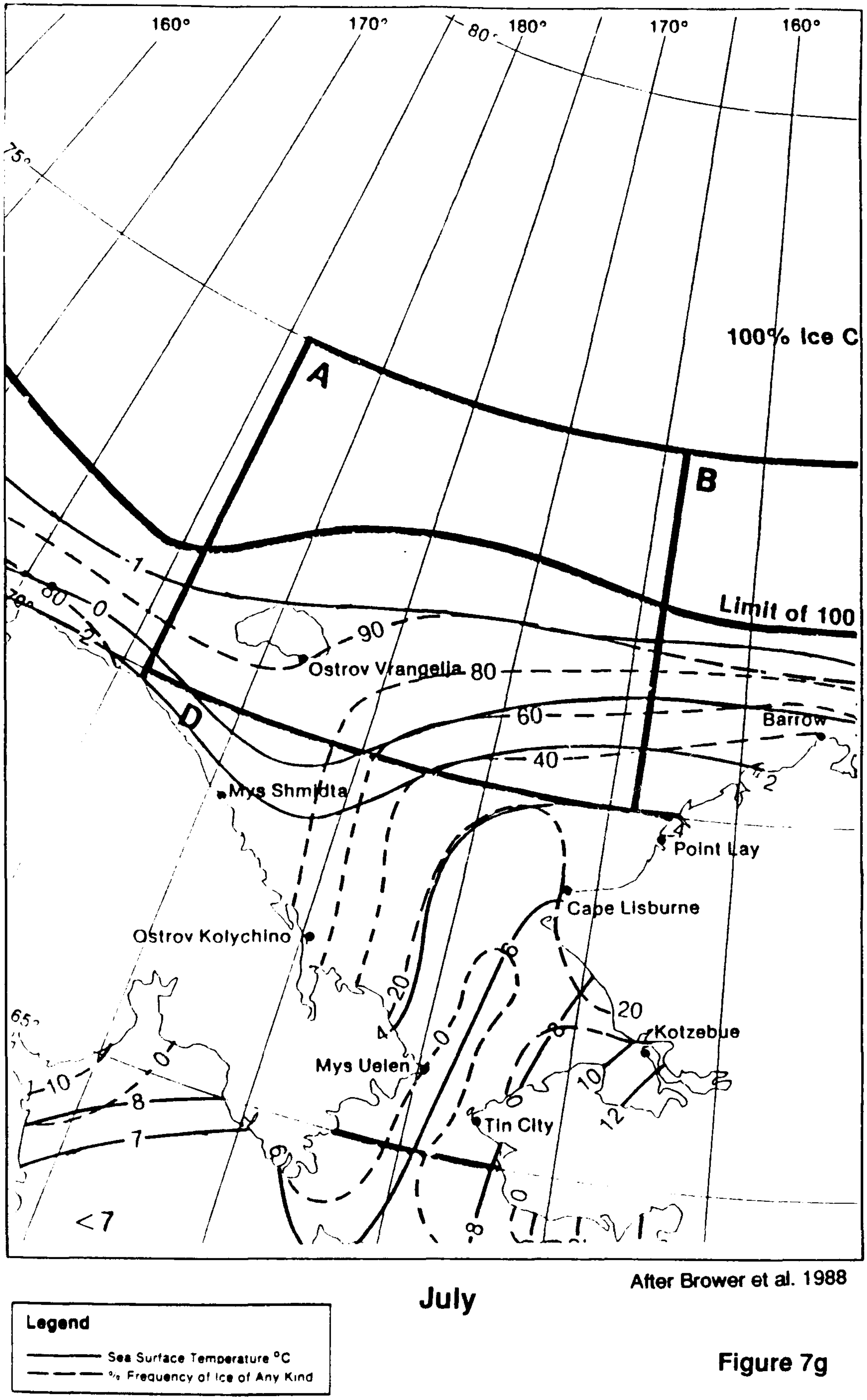
After Brower et al. 1988

June

Legend
Sea Surface Temperature °C
% Frequency of Ice of Any Kind

Figure 7f

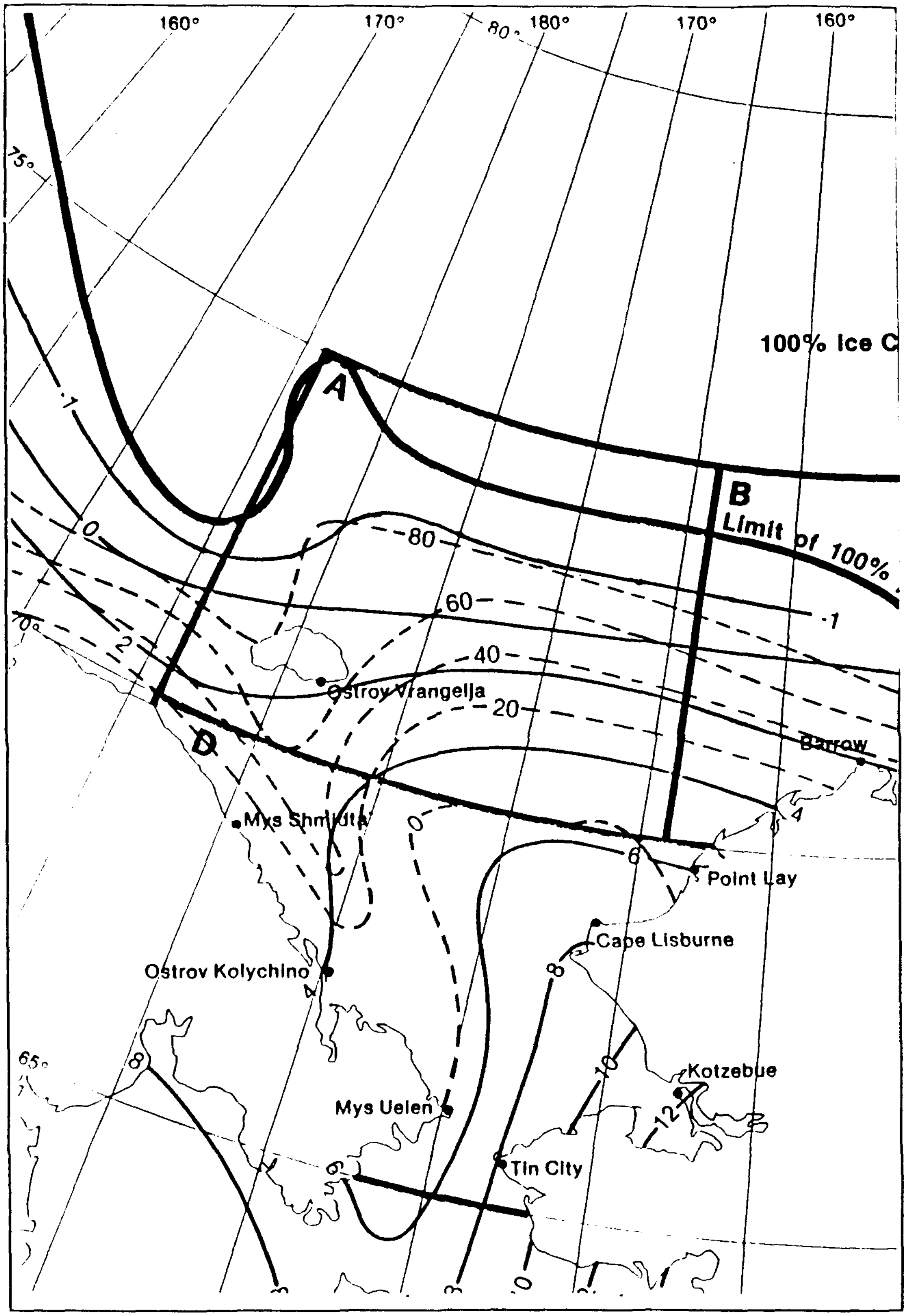
Sea Surface Temperature Means



After Brower et al. 1988

Figure 7g

Sea Surface Temperature Means



After Brower et al. 1988

August

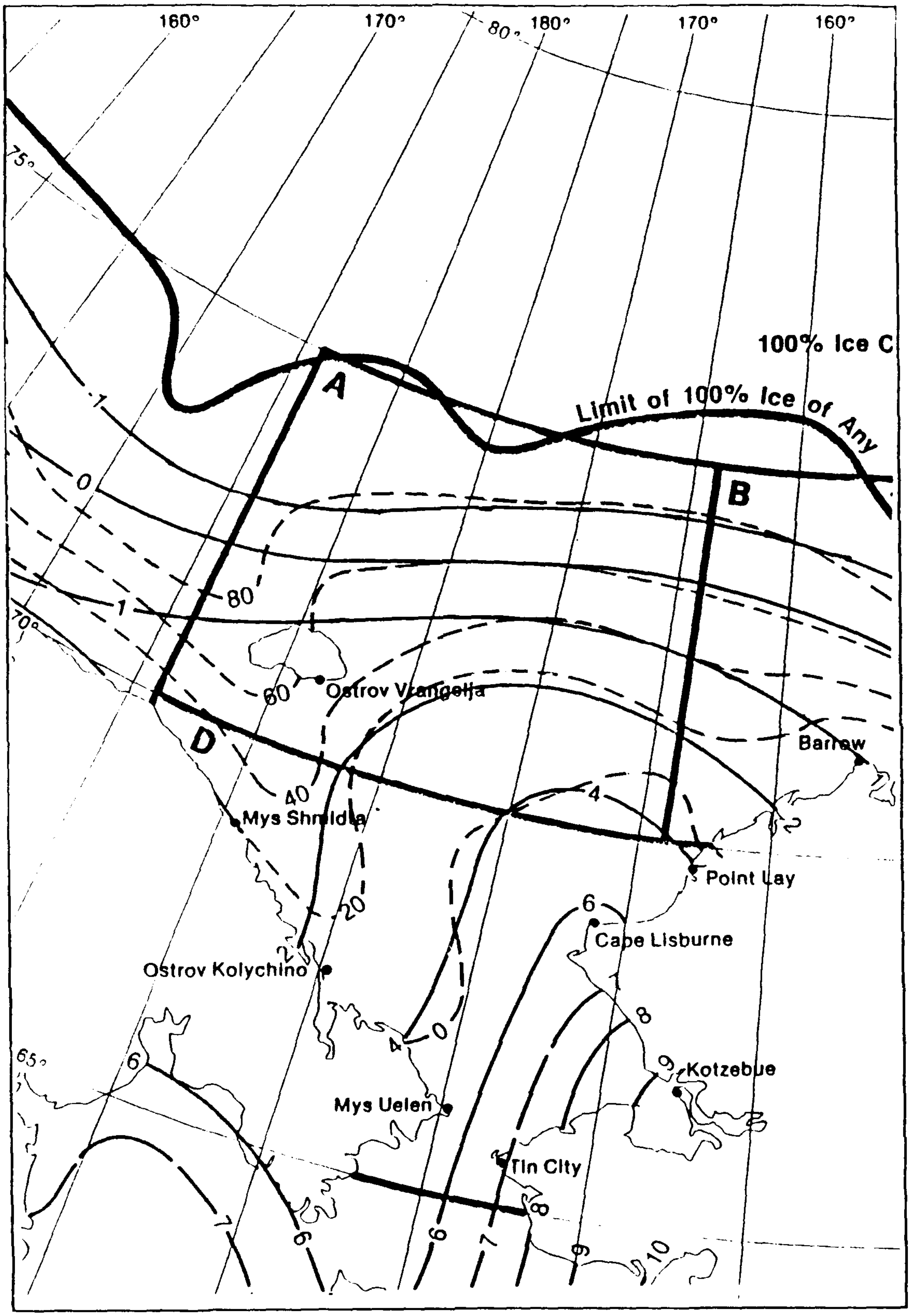
Legend

—— Sea Surface Temperature °C

– – – % Frequency of Ice of Any Kind

Figure 7h

Sea Surface Temperature Means



After Brower et al. 1988

September

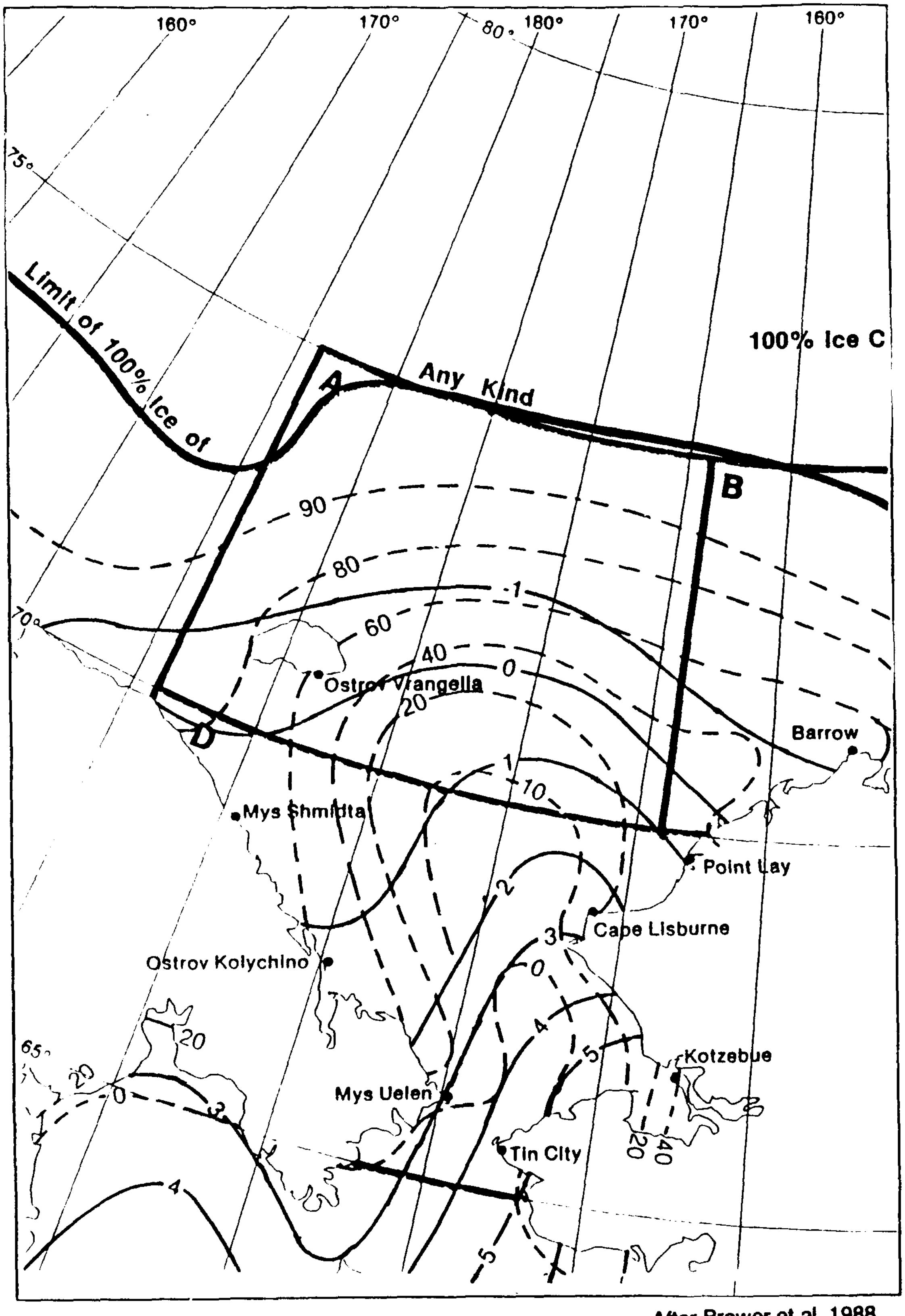
Legend

—— Sea Surface Temperature °C

– – – % Frequency of Ice of Any Kind

Figure 7i

Sea Surface Temperature Means

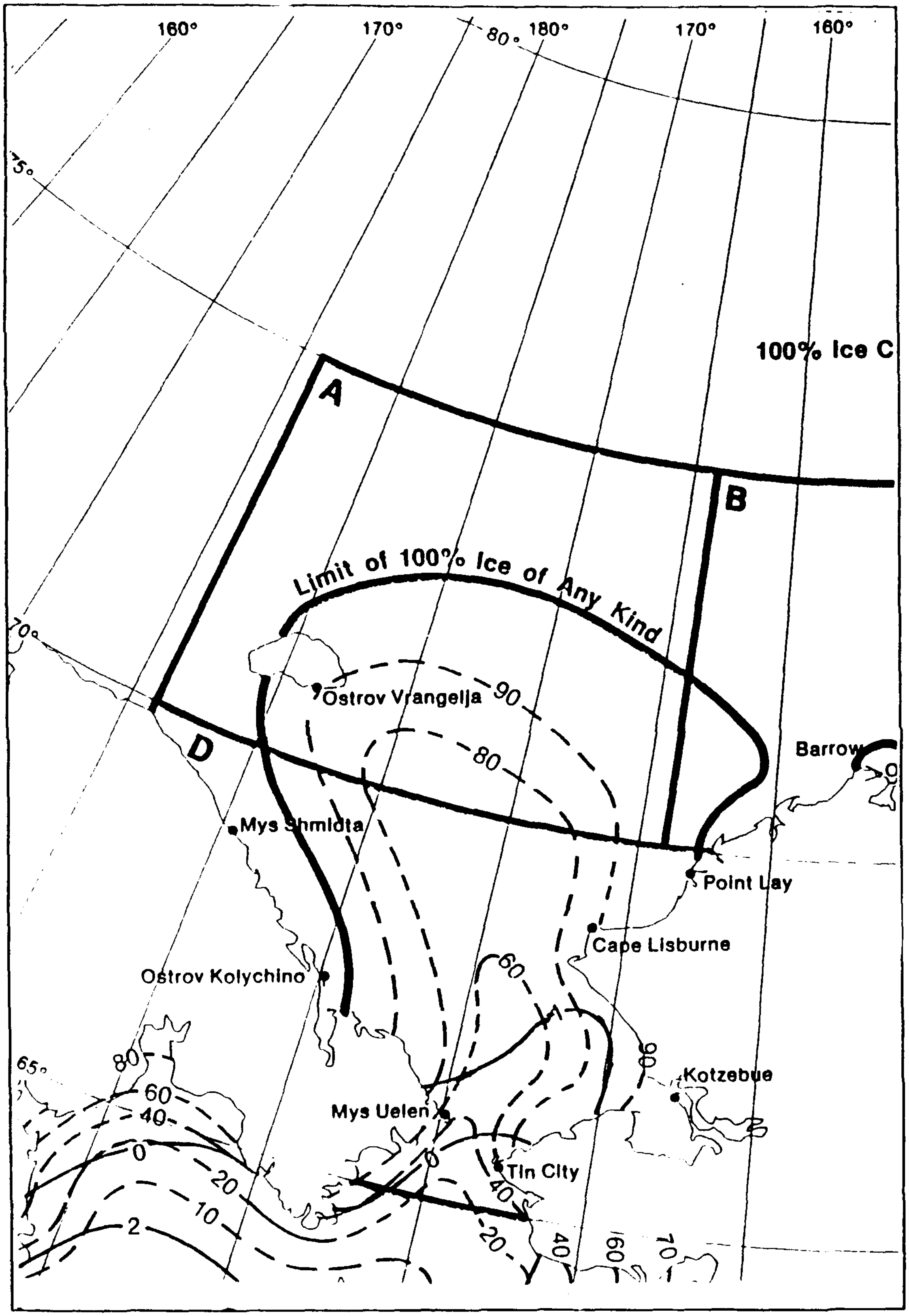


After Brower et al. 1988

October

Figure 7j

S· ı Surface Temperature Means



After Brower et al. 1988

Legend

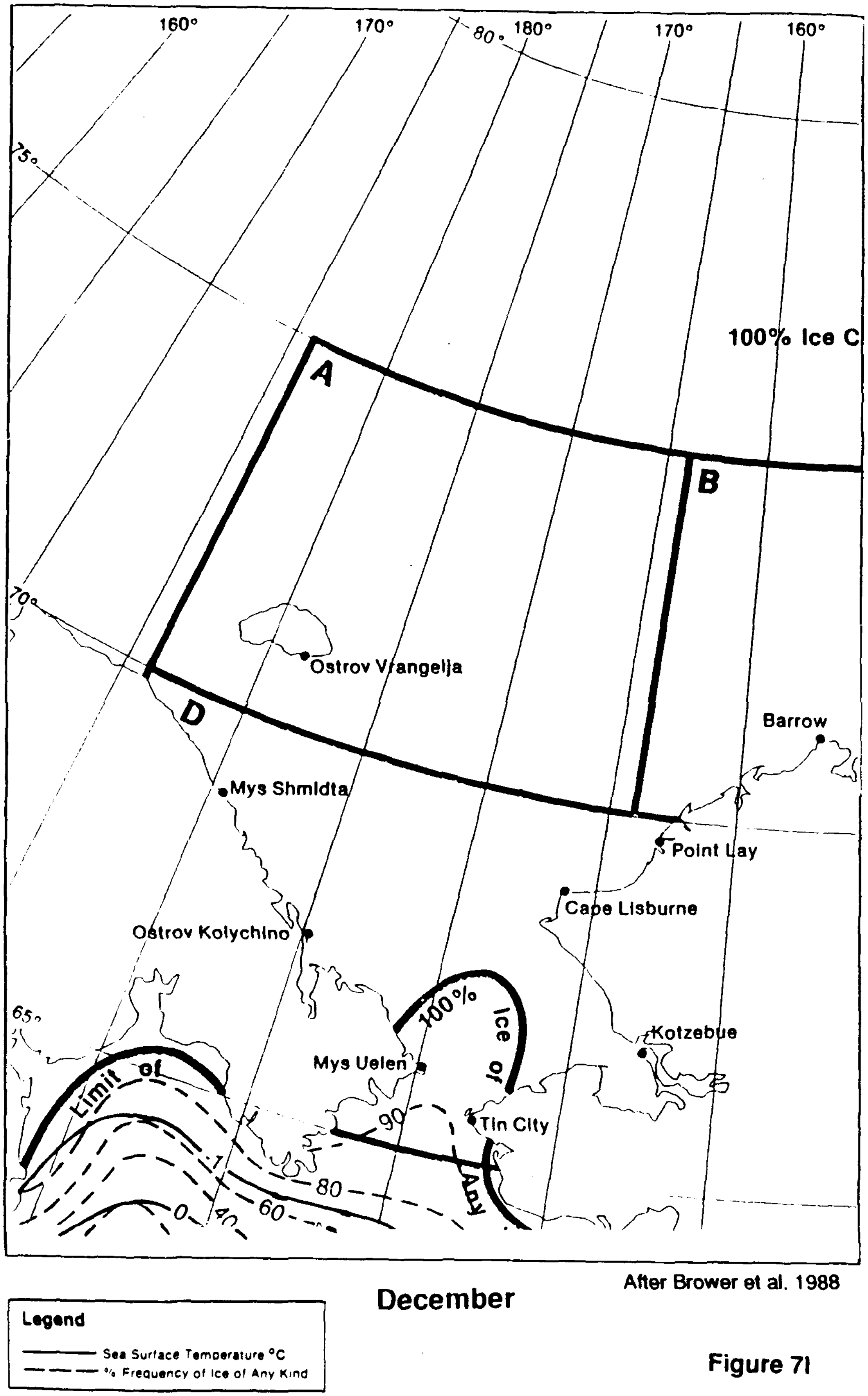
Sea Surface Temperature °C

% Frequency of Ice of Any Kind

November

Figure 7k

Sea Surface Temperature Means

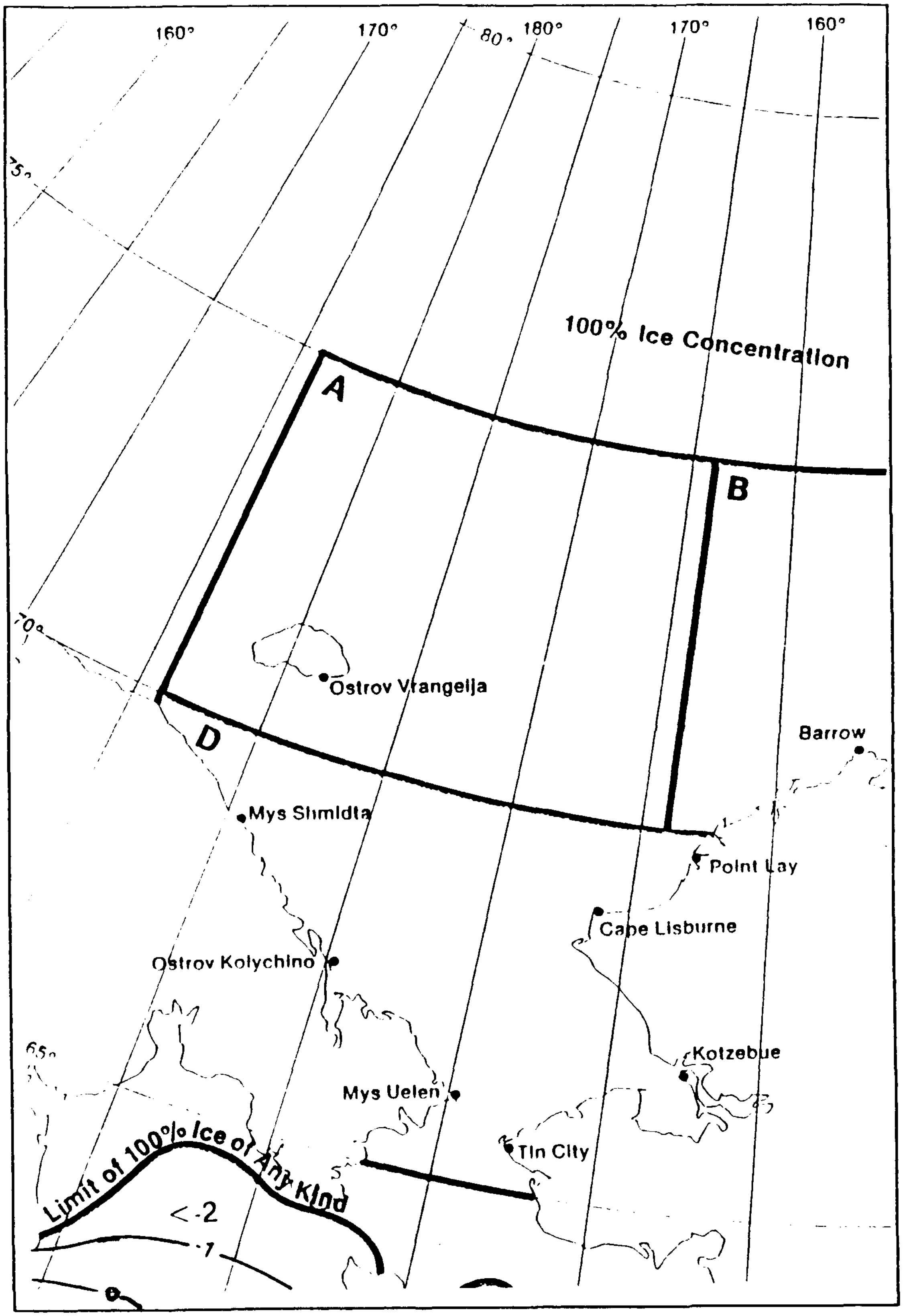


After Brower et al. 1988

December

Figure 71

Sea Surface Temperature Extremes



January

After Brower et al. 1988

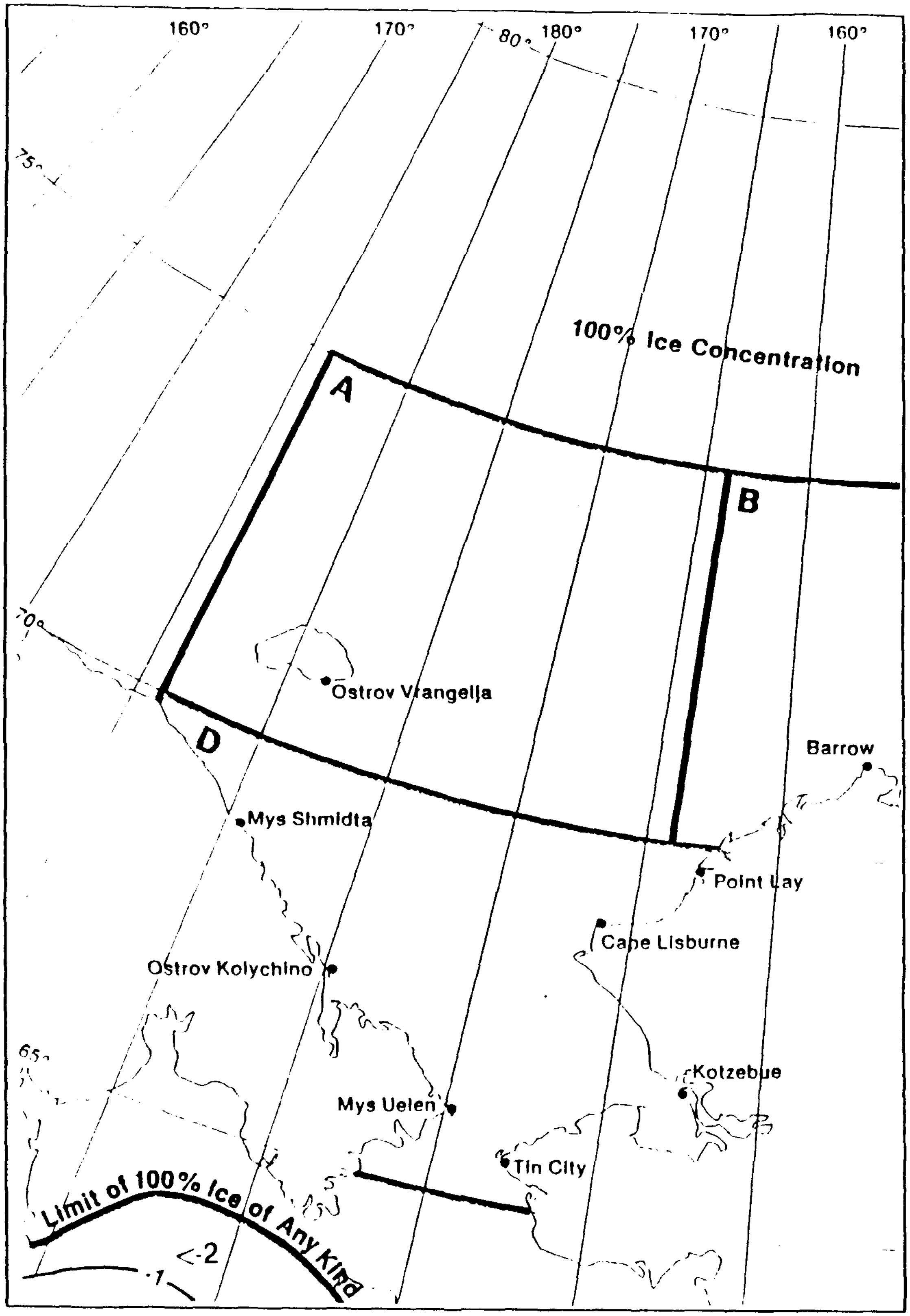
Legend

——— 99% Sea Surface Temperature (Max.)

— — — 1% Sea Surface Temperature (Min.)

Figure 8a

Sea Surface Temperature Extremes



February

After Brower et al. 1988

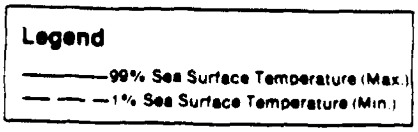


Figure 8b

Sea Surface Temperature Extremes

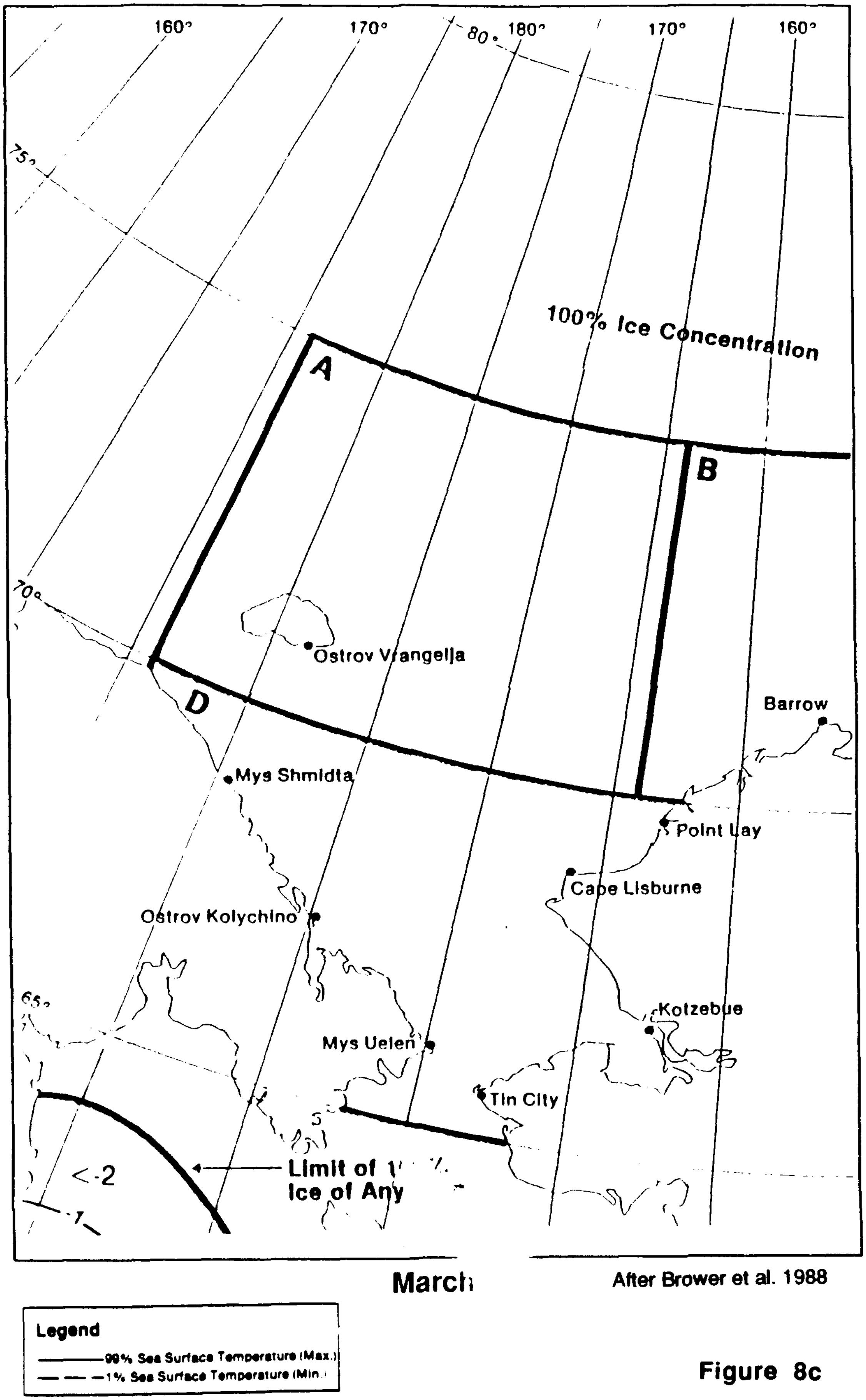
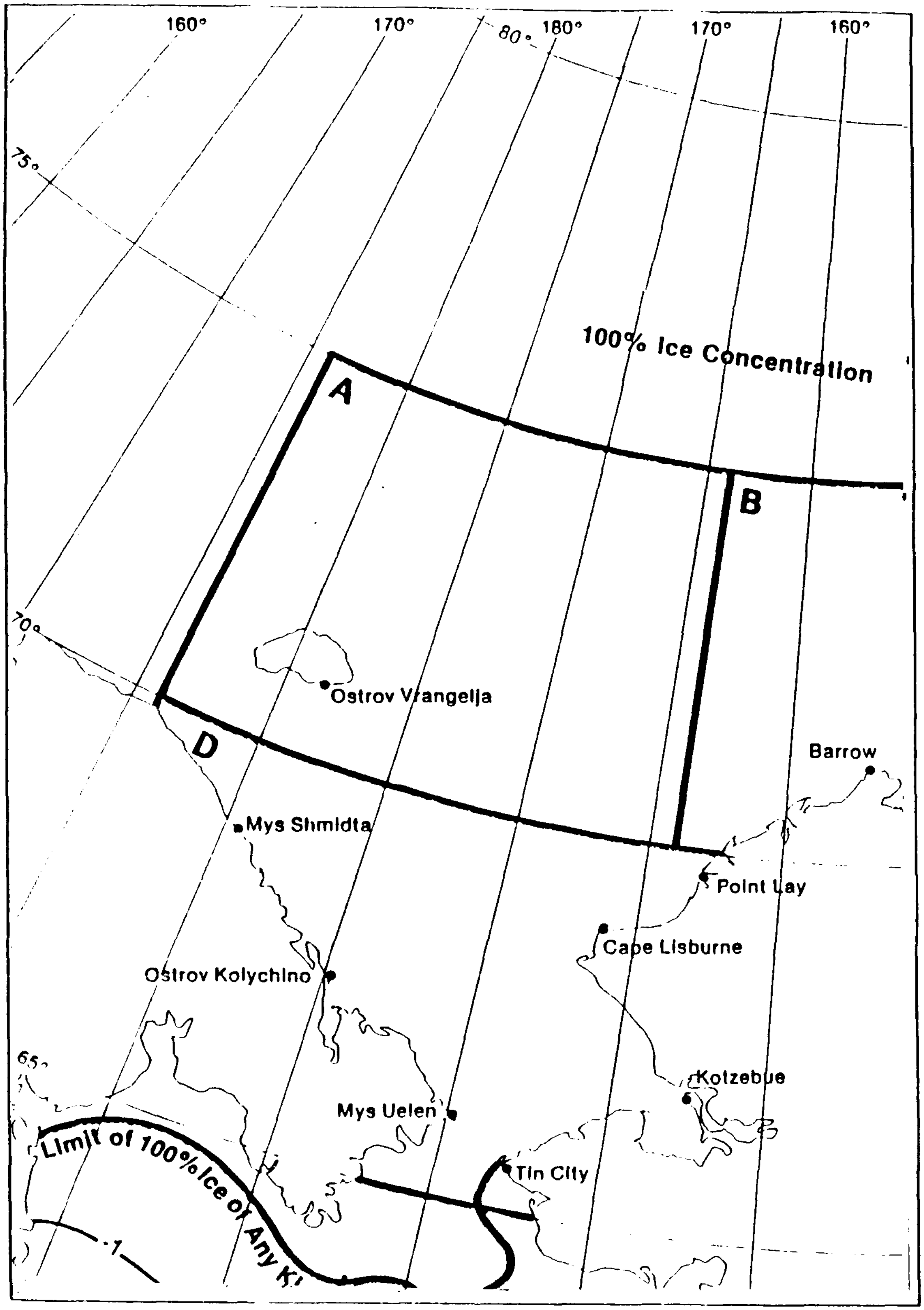


Figure 8c

Sea Surface Temperature Extremes



April

After Brower et al. 1988

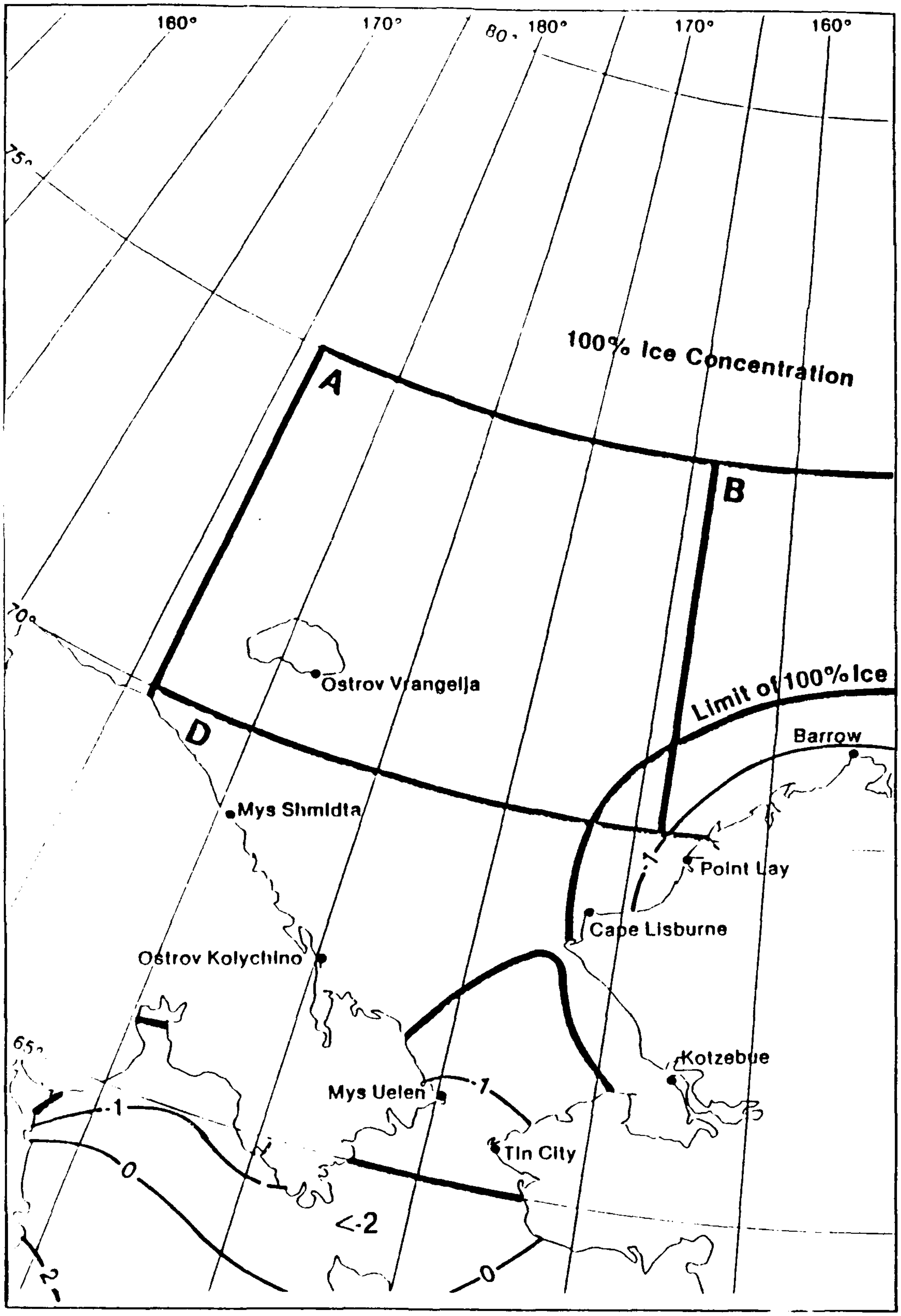
Legend

——— 99% Sea Surface Temperature (Max.)

— — — 1% Sea Surface Temperature (Min.)

Figure 8d

Sea Surface Temperature Extremes



May

After Brower et al. 1988

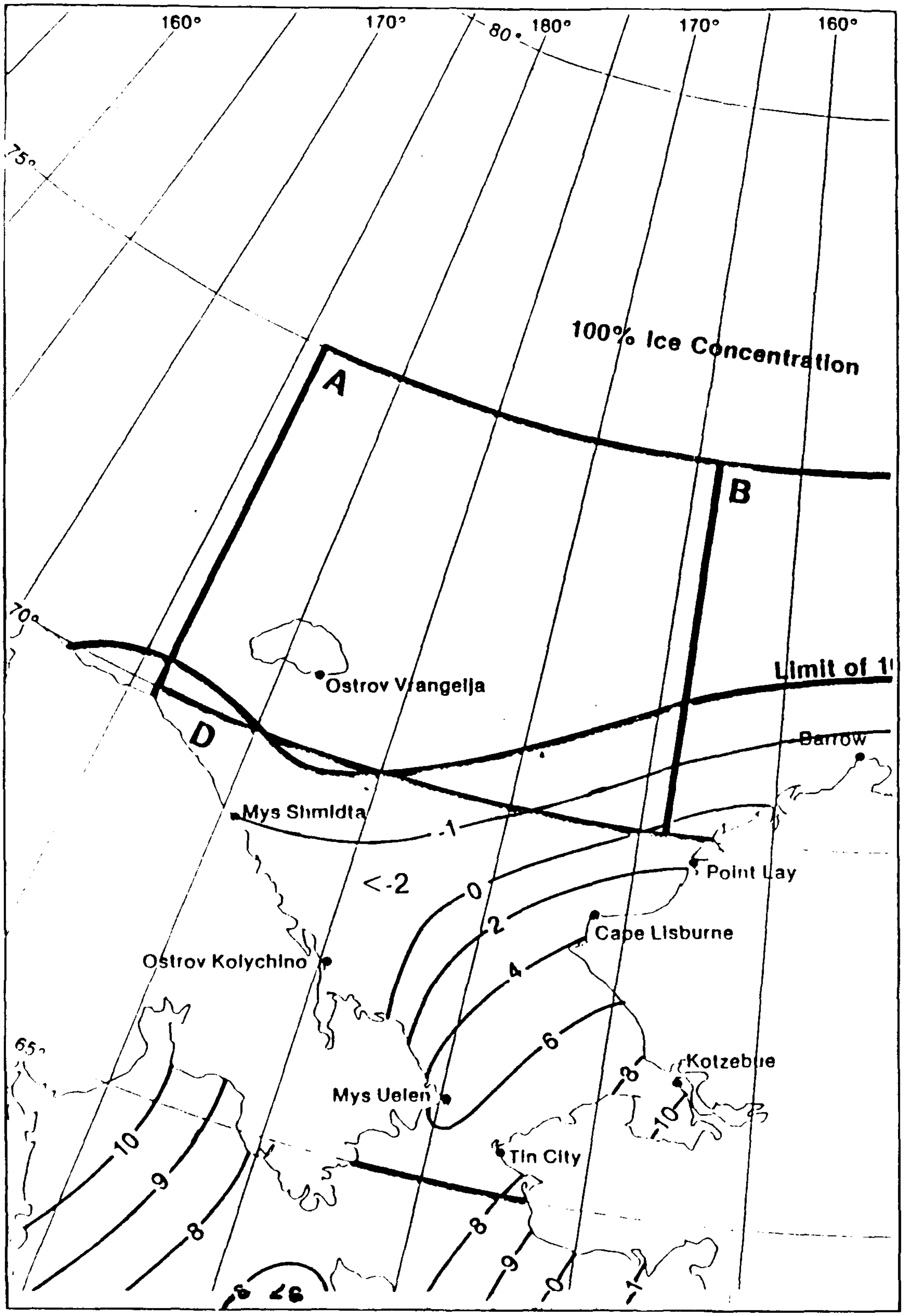
Legend

——— 99% Sea Surface Temperature (Max.)

— — — 1% Sea Surface Temperature (Min.)

Figure 8e

Sea Surface Temperature Extremes



June

After Brower et al. 1988

Legend

——— 99% Sea Surface Temperature (Max.)

— — — 1% Sea Surface Temperature (Min.)

Figure 8f

Sea Surface Temperature Extremes

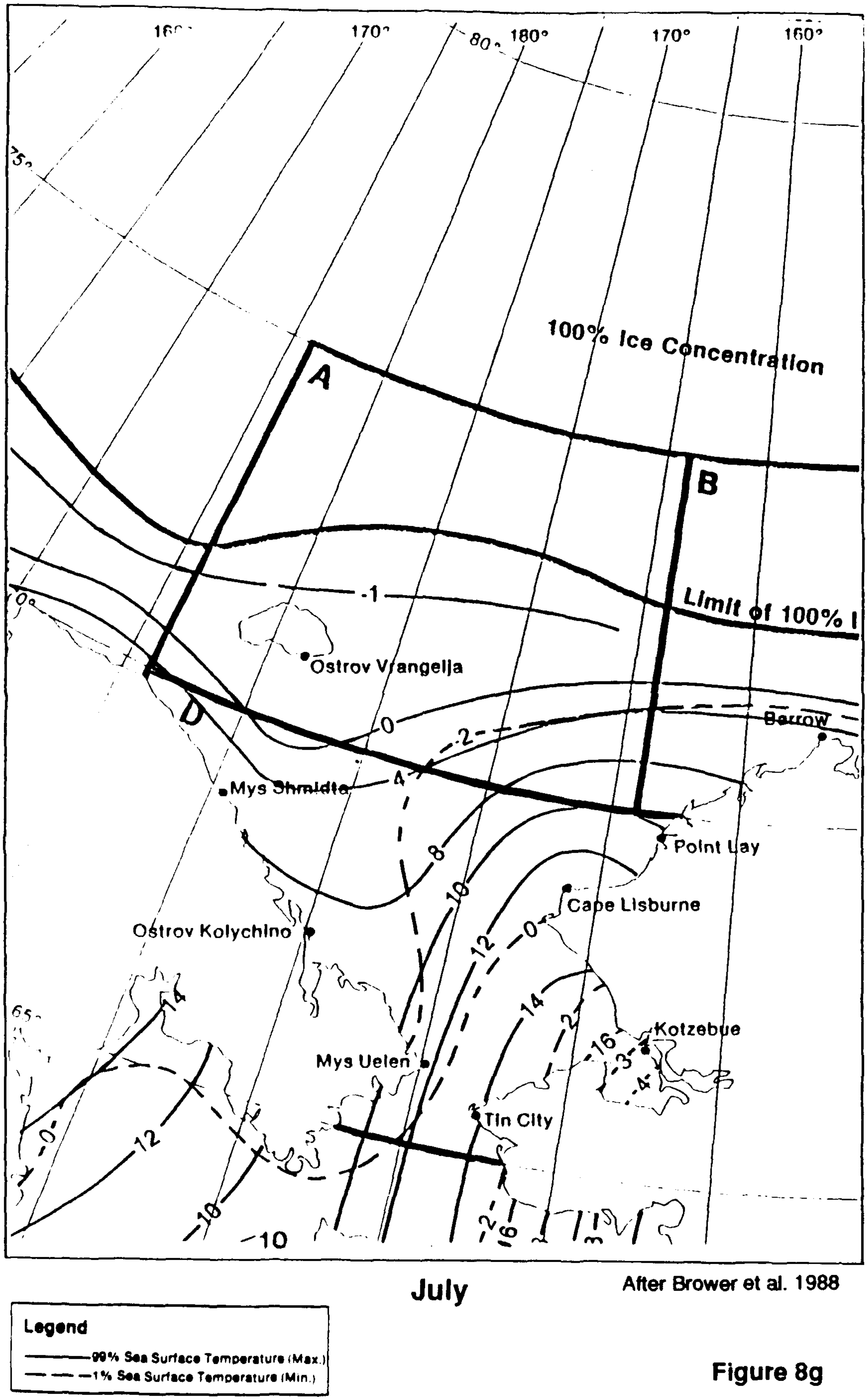
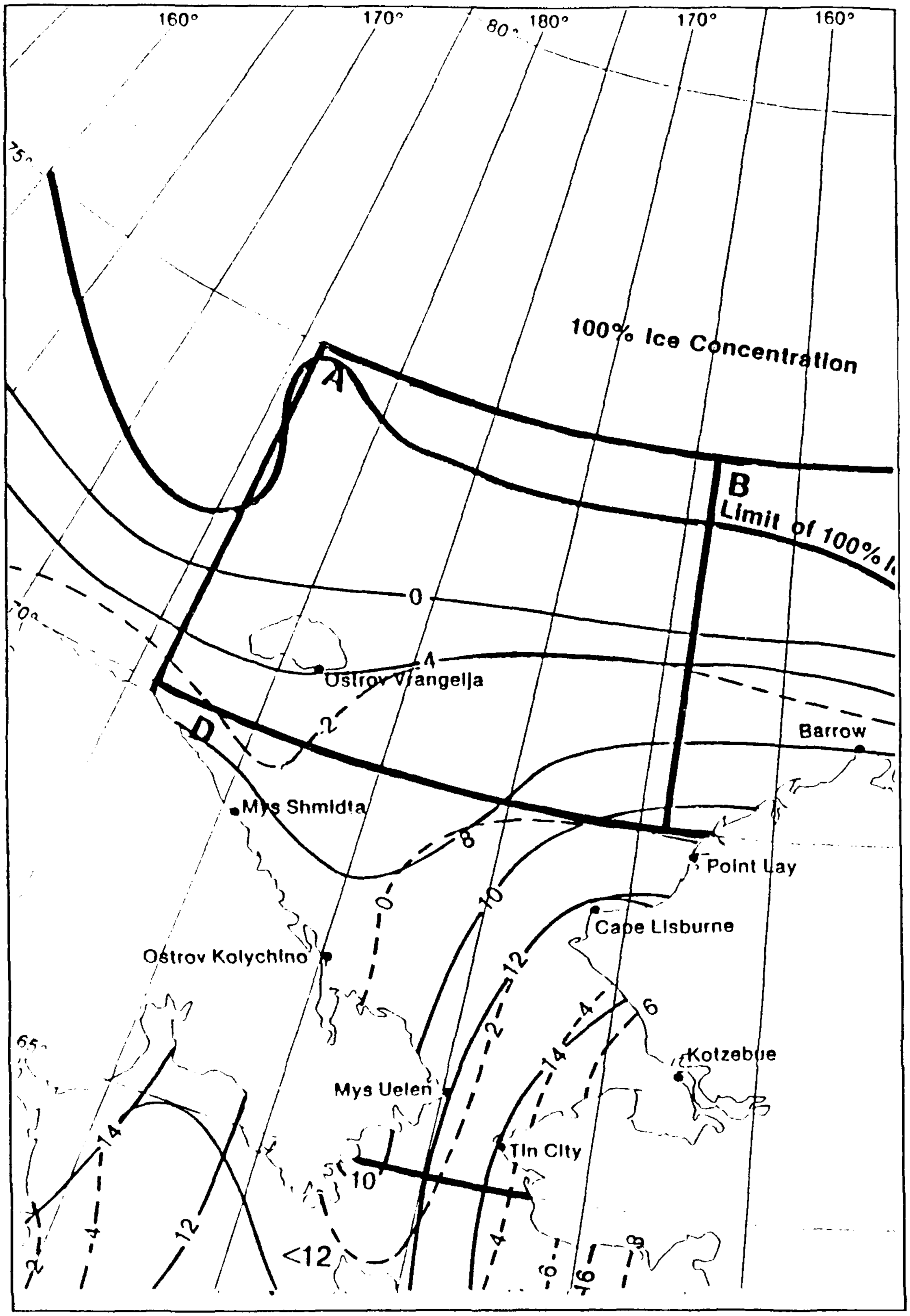


Figure 8g

Sea Surface Temperature Extremes



August

After Brower et al. 1988

Legend

——— 99% Sea Surface Temperature (Max.)

— — — 1% Sea Surface Temperature (Min.)

Figure 8h

Sea Surface Temperature Extremes

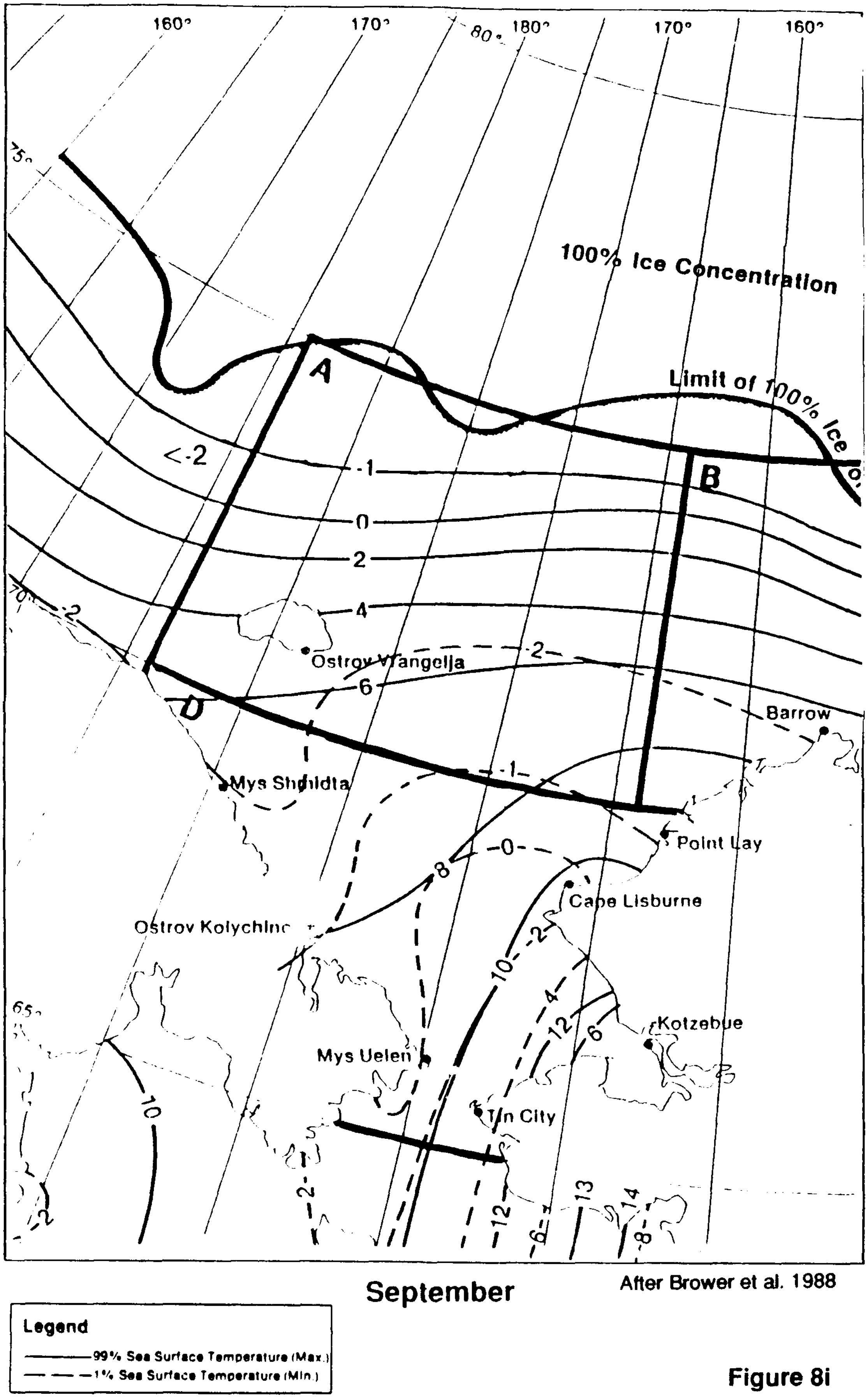
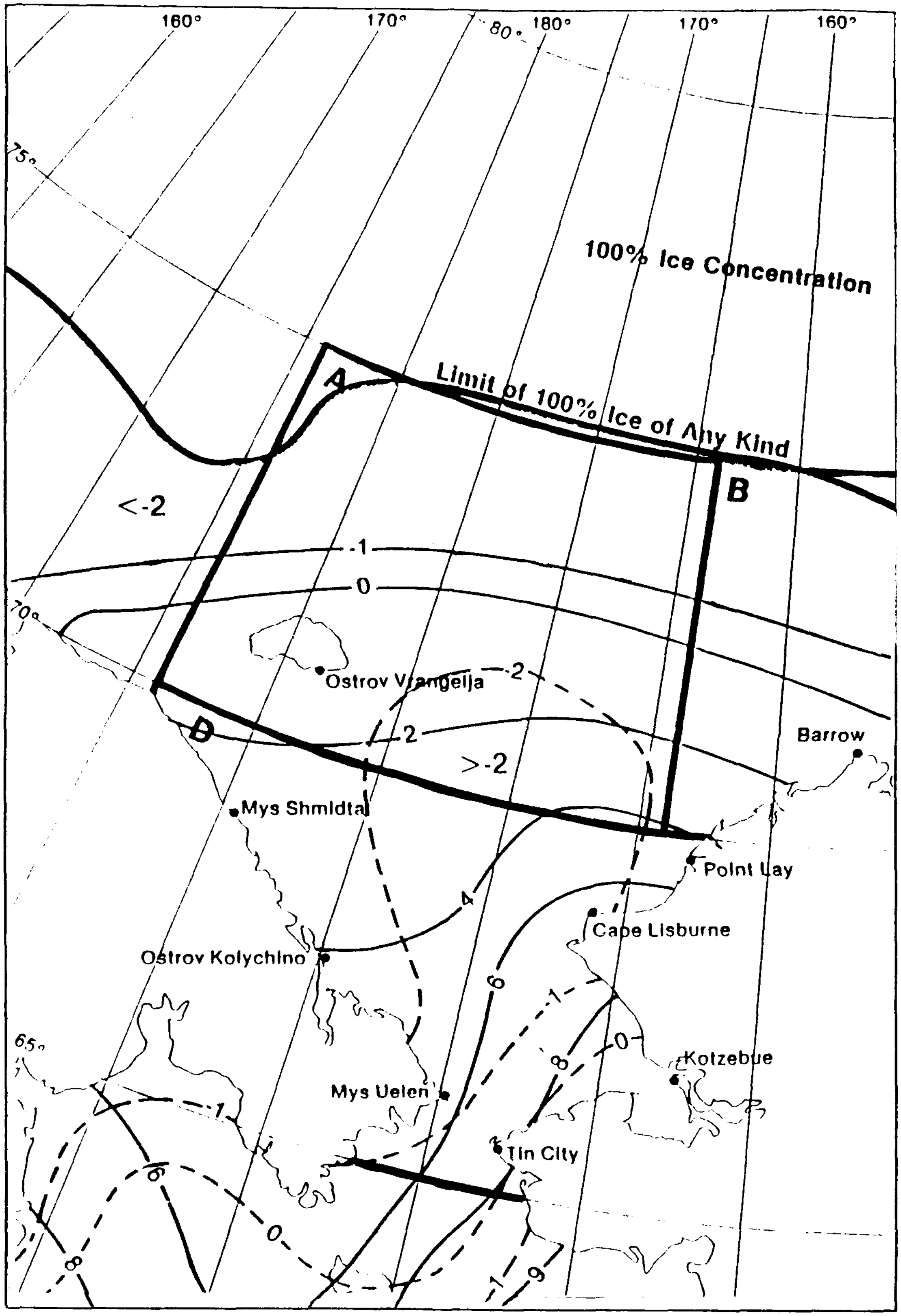


Figure 8i

Sea Surface Temperature Extremes



October

After Brower et al. 1988

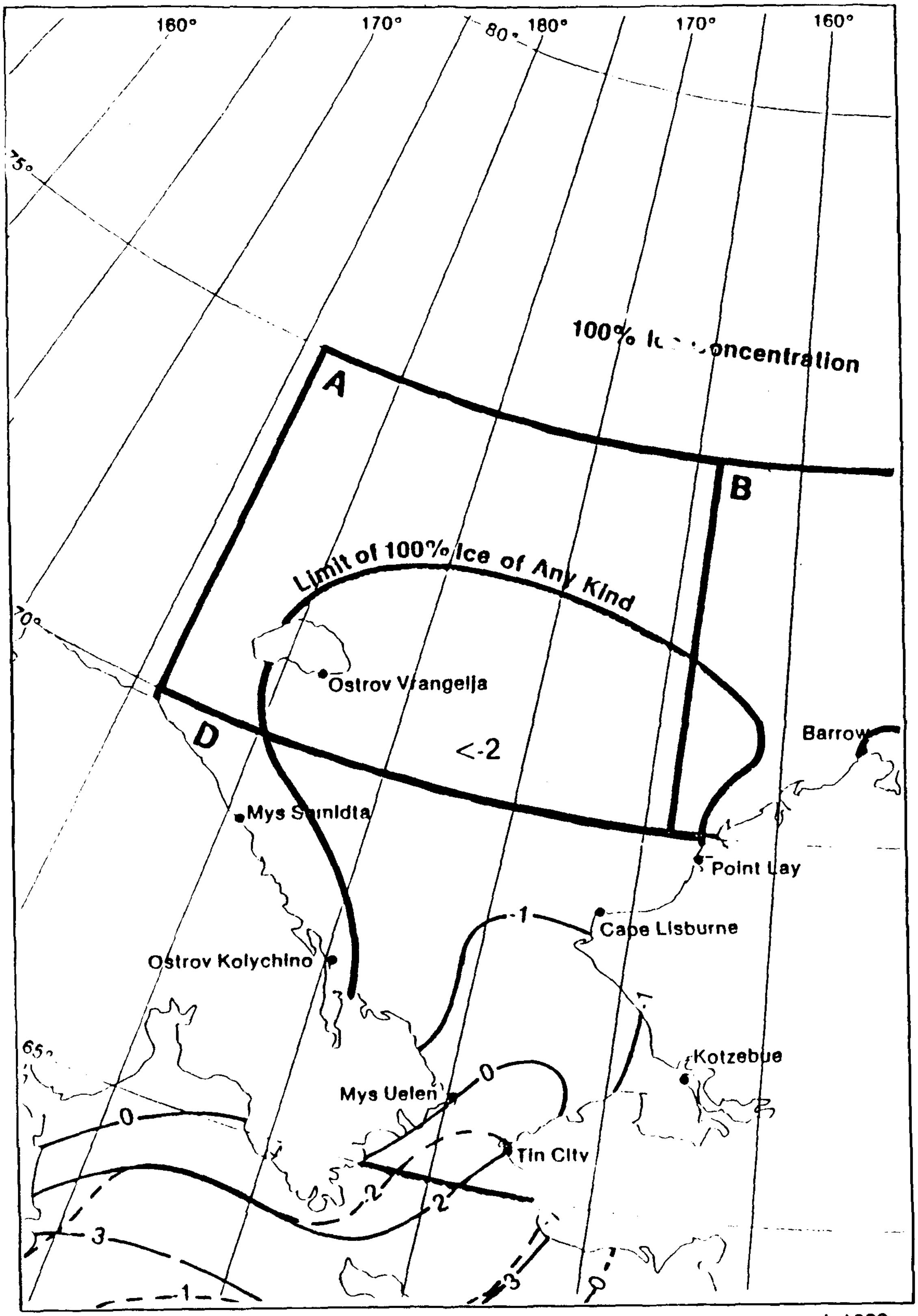
Legend

——— 99% Sea Surface Temperature (Max.)

— — — 1% Sea Surface Temperature (Min.)

Figure 8j

Sea Surface Temperature Extremes



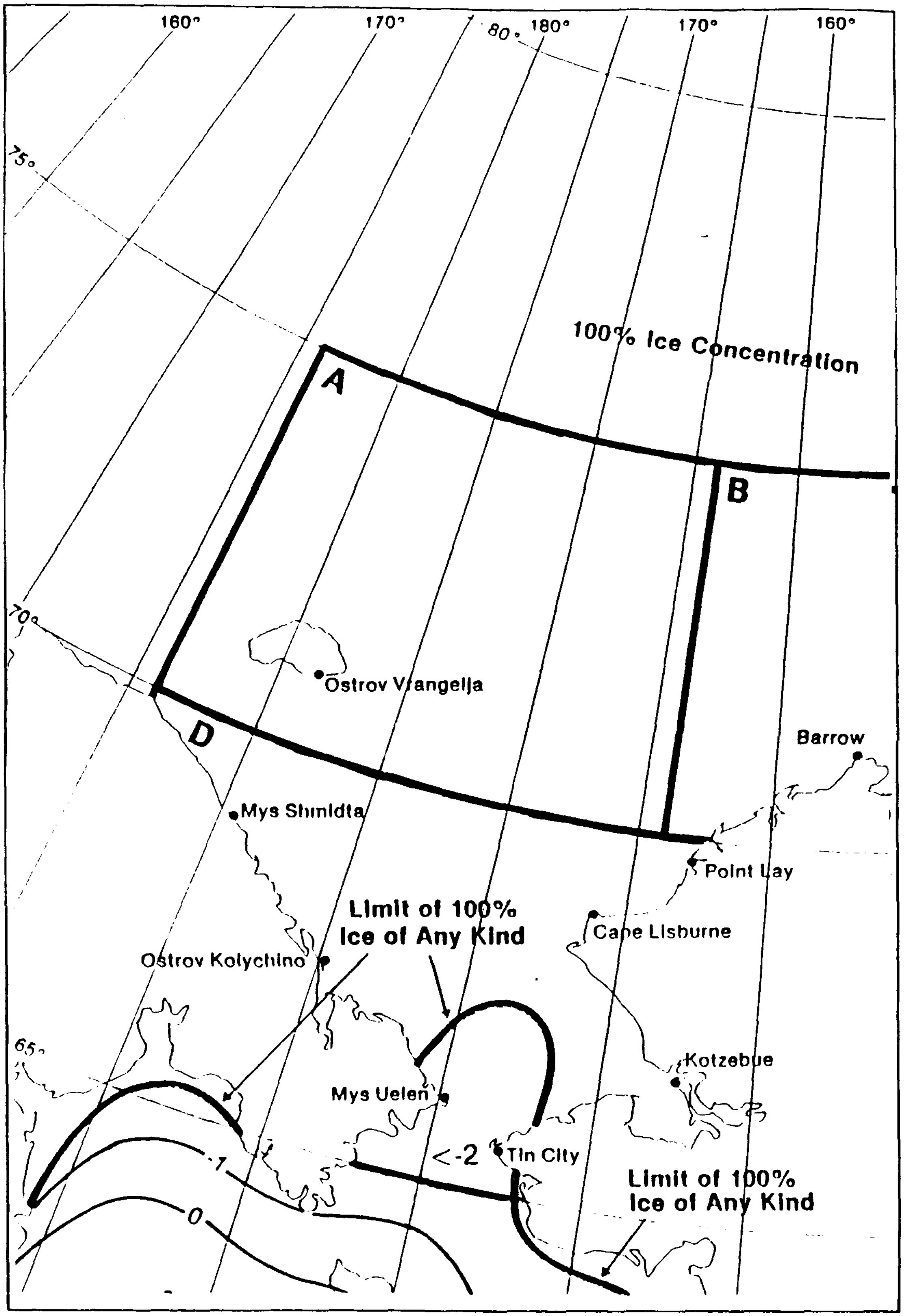
November

After Brower et al. 1988

Legend
- ——— 99% Sea Surface Temperature (Max.)
- — — — 1% Sea Surface Temperature (Min.)

Figure 8k

Sea Surface Temperature Extremes



December

After Brower et al. 1988

Legend

——— 99% Sea Surface Temperature (Max.)

— — — 1% Sea Surface Temperature (Min.)

Figure 8l

Figure 5 provides isopleths of surface and bottom temperature and salinity typical of midsummer conditions.

Figure 6 gives recent August/September surface and bottom temperature and salinity reported by Johnson (1988).

Figures 7a-7l show monthly sea surface temperature mean isopleths and the frequency of ice of any kind.

Figures 8a-8l show monthly sea surface temperature extremes.

WAVES

The Chukchi Sea is almost totally covered with ice in the winter season and is partially covered with ice or broken ice during the summer. This ice cover dampens wave formation so that sea greater than 1.5m occur less than 20% of the time and then only during summer months from Point Barrow south. Figures 9a-9d show the most updated data on wave height distribution by month in three areas: Marine Area D (65°-70°N; 160°E to 176°W); Marine Area A (70-75°N; 164°E to 176°W); and Marine Area B (70-75°N; 144°-164°E).

Graphs: Wave height thresholds

Wave height frequencies.

WAVE HEIGHT (M)	%
0–0.5	10.0
1–1.5	20.0
2–2.5	30.0
3–3.5	20.0
4–5.5	10.0
≧6.0	10.0
N=	1363

Percent frequency of various ranges within the area.

(30.0% of all observed wave heights were in the range 2 to 2.5 meters.)

N = Observation count.

Wave data for these tables were selected from the higher of sea or swell when both were reported.

Figure 9

Wave Height Thresholds

January

Marine Area A

No Data Available

Marine Area B

No Data Available

Marine Area D

No Data Available

February

Marine Area A

No Data Available

Marine Area B

WAVE HEIGHT (M)	%
0–0.5	100.0
1–1.5	0.0
2–2.5	0.0
3–3.5	0.0
4–5.5	0.0
≥6.0	0.0
N=	16

Marine Area D

WAVE HEIGHT (M)	%
0–0.5	93.3
1–1.5	0.0
2–2.5	6.7
3–3.5	0.0
4–5.5	0.0
≥6.0	0.0
N=	30

March

Marine Area A

WAVE HEIGHT (M)	%
0–0.5	89.6
1–1.5	10.4
2–2.5	0.0
3–3.5	0.0
4–5.5	0.0
≥6.0	0.0
N=	77

Marine Area B

WAVE HEIGHT (M)	%
0–0.5	100.0
1–1.5	0.0
2–2.5	0.0
3–3.5	0.0
4–5.5	0.0
≥6.0	0.0
N=	60

Marine Area D

WAVE HEIGHT (M)	%
0–0.5	93.8
1–1.5	2.5
2–2.5	2.5
3–3.5	1.3
4–5.5	0.0
≥6.0	0.0
N=	80

Figure 9a

Wave Height Thresholds

Marine Area A

WAVE HEIGHT (M)	%
0–0.5	87.2
1–1.5	0.0
2–2.5	12.8
3–3.5	0.0
4–5.5	0.0
≥6.0	0.0
N=	39

Marine Area B

No Data Available

Marine Area D

WAVE HEIGHT (M)	%
0–0.5	99.0
1–1.5	1.0
2–2.5	0.0
3–3.5	0.0
4–5.5	0.0
≥6.0	0.0
N=	98

April

Marine Area A

No Data Available

Marine Area B

No Data Available

Marine Area D

WAVE HEIGHT (M)	%
0–0.5	83.6
1–1.5	16.4
2–2.5	0.0
3–3.5	0.0
4–5.5	0.0
≥6.0	0.0
N=	122

May

Marine Area A

No Data Available

Marine Area B

No Data Available

Marine Area D

WAVE HEIGHT (M)	%
0–0.5	83.0
1–1.5	15.0
2–2.5	1.7
3–3.5	0.2
4–5.5	0.0
≥6.0	0.0
N=	407

June

Figure 9b

Wave Height Thresholds

Marine Area A

WAVE HEIGHT (M)	%
0–0.5	79.5
1–1.5	19.0
2–2.5	1.5
3–3.5	0.0
4–5.5	0.0
≥6.0	0.0
N=	200

Marine Area B

WAVE HEIGHT (M)	%
0–0.5	88.4
1–1.5	9.2
2–2.5	1.0
3–3.5	0.5
4–5.5	0.8
≥6.0	0.0
N=	1115

Marine Area D

WAVE HEIGHT (M)	%
0–0.5	58.9
1–1.5	33.1
2–2.5	6.3
3–3.5	1.2
4–5.5	0.3
≥6.0	0.1
N=	2104

July

Marine Area A

WAVE HEIGHT (M)	%
0–0.5	74.4
1–1.5	21.8
2–2.5	2.5
3–3.5	0.8
4–5.5	0.6
≥6.0	0.0
N=	363

Marine Area B

WAVE HEIGHT (M)	%
0–0.5	82.9
1–1.5	14.1
2–2.5	1.9
3–3.5	0.4
4–5.5	0.6
≥6.0	0.0
N=	2490

Marine Area D

WAVE HEIGHT (M)	%
0–0.5	45.4
1–1.5	41.8
2–2.5	9.6
3–3.5	2.3
4–5.5	0.8
≥6.0	0.2
N=	1838

August

Marine Area A

WAVE HEIGHT (M)	%
0–0.5	50.8
1–1.5	30.6
2–2.5	12.2
3–3.5	3.3
4–5.5	1.9
≥6.0	1.2
N=	516

Marine Area B

WAVE HEIGHT (M)	%
0–0.5	68.4
1–1.5	23.8
2–2.5	5.6
3–3.5	1.6
4–5.5	0.6
≥6.0	0.0
N=	1591

Marine Area D

WAVE HEIGHT (M)	%
0–0.5	30.4
1–1.5	42.4
2–2.5	18.1
3–3.5	6.2
4–5.5	2.5
≥6.0	0.4
N=	1830

September

Figure 9c

Wave Height Thresholds

October

Marine Area A

WAVE HEIGHT (M)	%
0–0.5	77.3
1–1.5	12.2
2–2.5	9.4
3–3.5	0.0
4–5.5	1.1
≥6.0	0.0
N=	181

Marine Area B

WAVE HEIGHT (M)	%
0–0.5	80.5
1–1.5	14.4
2–2.5	4.7
3–3.5	0.0
4–5.5	0.4
≥6.0	0.0
N=	236

Marine Area D

WAVE HEIGHT (M)	%
0–0.5	24.7
1–1.5	41.0
2–2.5	22.0
3–3.5	9.0
4–5.5	2.0
≥6.0	1.3
N=	700

November

Marine Area A

No Data Available

Marine Area B

WAVE HEIGHT (M)	%
0–0.5	84.6
1–1.5	7.7
2–2.5	7.7
3–3.5	0.0
4–5.5	0.0
≥6.0	0.0
N=	13

Marine Area D

WAVE HEIGHT (M)	%
0–0.5	28.6
1–1.5	28.6
2–2.5	30.6
3–3.5	4.1
4–5.5	8.2
≥6.0	0.0
N=	49

December

Marine Area A

No Data Available

Marine Area B

No Data Available

Marine Area D

No Data Available

Figure 9d

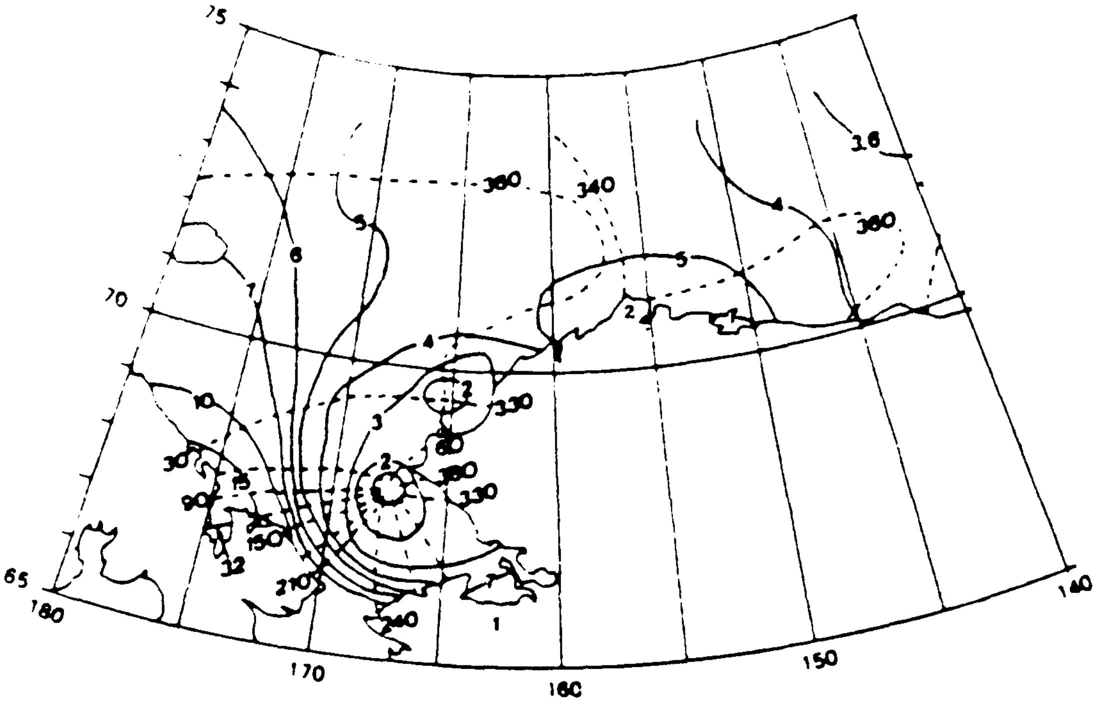
TIDES

The Bering Strait acts as a barrier to any significant tidal effect from the Pacific Ocean so that the tidal progression in the Chukchi Sea extends southward from the Arctic ocean. The tides north of the Bering Strait are semidiurnal along the Siberian Coast and mixed along the Alaskan Coast. Compared to the effects of wind and changes in atmospheric pressure, the effects of lunar tides on water level are minor. In addition, the seasonal ice cover slows the arrival and decreases the amplitudes of the tides. The tidal range in the Chukchi Sea is small, usually 1 foot or less, except in semi-enclosed areas such as Kotzebue Sound where the mean tidal range is 2.1 feet.

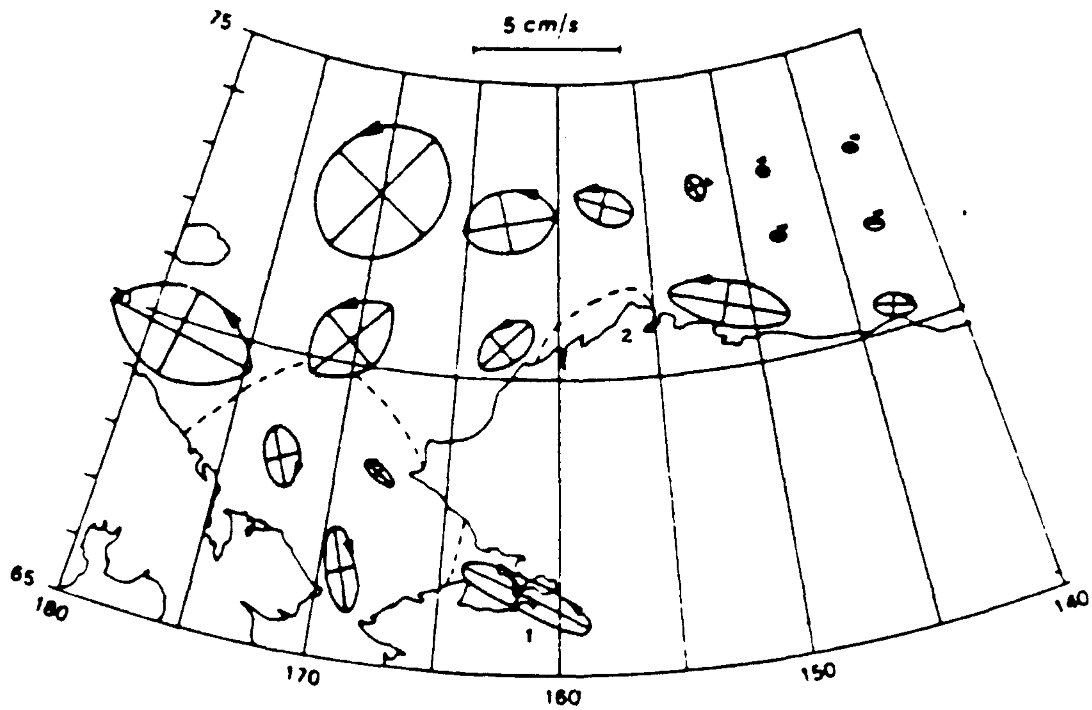
To correct in part for the sparse observations of tides in the Chukchi Sea, a pattern of the M_2 component was generated by Kowalik and Matthews (1982). The results of their computations of co-tidal and co-range using the equations of motion and continuity in spherical coordinates are shown in figure 10A. Keep in mind that the M_2 component is not the whole tide but is the largest of the components going to make up the tide. Tidal co-range decreases continuously as one goes north and east so that there is a dramatic difference between tidal co-range in the southern end of the study area (Kiwalik/Kotzebue Sound) and at Point Barrow in the northern end. Table 2 contrasts the tidal characteristics at Kiwalik (1) versus Point Barrow (2). Actual astronomical tide ranges are about half a foot along the Chukchi Sea coast from Cape Lisburne to Point Barrow. The tide range in Kotzebue Sound is greater at 2 to 2 1/2 ft. The tidal currents (ellipses, figure 10B) are highest in the north and west, except for the Kotzebue Sound System. These modest tidal currents are nonetheless quite significant to the total flow through the area.

Table 2. Tidal range characteristics (feet) for the Chukchi Sea area. Adapted from Brower, et al. (1988 prepublication version) from NOS/NOAA (1985).

Tidal Type	Kiwalik (1)	Point Barrow (2)
Average Diurnal Range	2.7	0.4
Maximum Diurnal Range	4.2	0.7
Minimum Diurnal Range	0.4	0.1
Maximum Tidal Height	3.4	0.5
Minimum Tidal Height	-0.8	-0.1



A. Co-tidal (broken line) and co-range (continuous) lines of dominant M_2 tide for Chukchi Sea area. Phase angles (degrees are referred to Greenwich (solar time)); amplitudes are in cm.

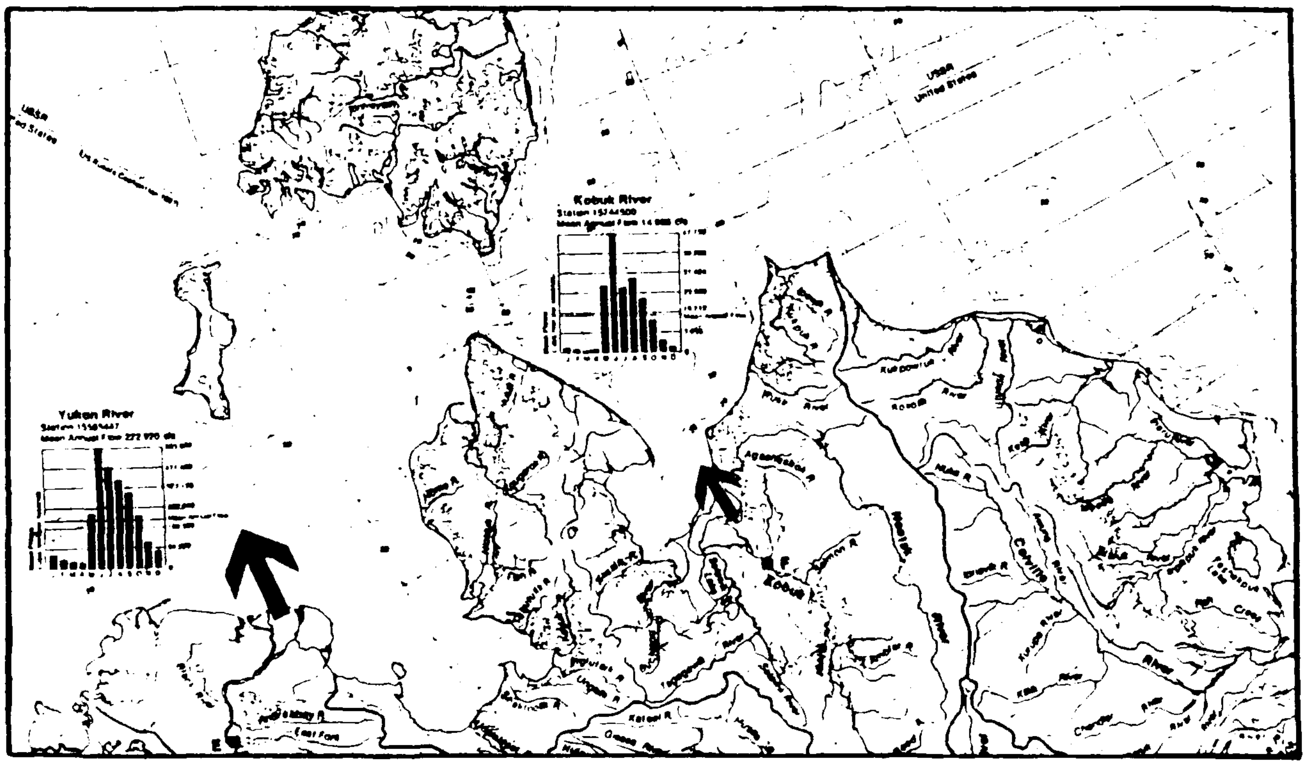


B. Tidal ellipses where arrows indicate direction of rotation and broken lines indicate boundaries between areas with different rotation. From Kowalik and Matthews (1982).

Figure 10

RIVER DISCHARGE

Figure 11 shows many small rivers on USSR and northern Alaskan coasts which conduct small potential inputs of freshwater to the Chukchi Sea through river discharge, lagoon or inlet systems along the coast. Because of the general low precipitation and the interception of some of the regional melt into the Colville River watershed going to the Beaufort Sea, most of these small rivers and creeks cause only transient and localized modifications to flow and salinity in lagoon systems or near the coast. The volumetric flow rate for only the Kobuk River draining into Kotzebue Sound has been determined (USGS 1973). The Kobuk River has a drainage area of 6570 square miles (about 2% of the Yukon River), average, maximum and minimum flows of 14,968, 95,000, and 700 cfs (cubic feet per second) respectively, and average annual runoff of 18 inches. For comparison, the Kobuk River average flow is less than 7% of the average Yukon River flow (222,920 cfs, figure 11). Seasonally some lower salinity water near the coast around Kotzebue Sound may have originated as Kobuk River discharge (Handlers 1977). Across the Chukchi Sea area, ice-melt water and modified Alaskan or Siberian coastal water appears to be more important than river discharge in determining water mass characteristics.



River drainage pattern for Chukchi Sea and contiguous Norton Sound area. Kobuk River flow is compared with the much larger Yukon River. (After NOAA 1988).

Figure 11

OIL SPILL TRANSPORT

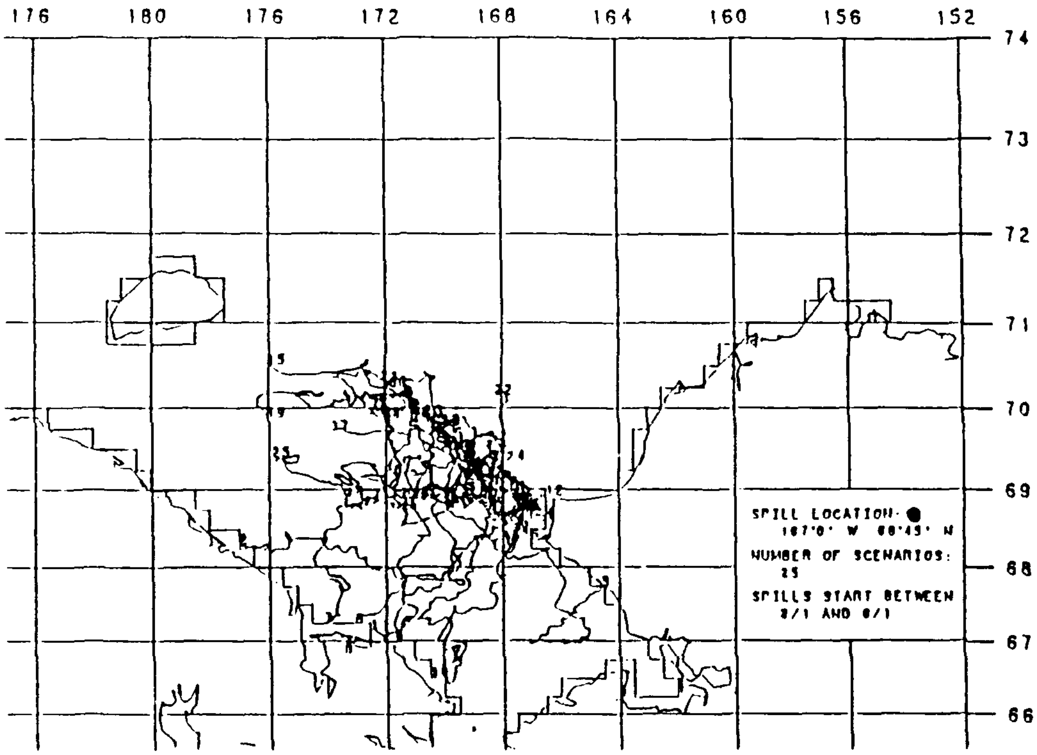
The fate of spilled oil in the Chukchi Sea depends upon a complex interaction of four principal processes: currents and all circulation components; surface wind wave drift (Stoke's drift); ice distribution; and weather patterns. Reed et al. (1987) have used available information about these variables (winds; heavy, normal, and light ice cover, currents) in a oil spill trajectory model for the Chukchi and Beaufort Seas. This model simulates the transport and spreading behavior in both open and ice covered waters. Figures 12a-12d show the 25 trajectories that were generated by inputting stochastic 30-day historical data for several of the five launch points and for spills occurring at different seasons of the year. These figures illustrate the extreme variability possible for oil spill trajectories during these seasons. Generally, the spills moved away north and west from the Alaskan coast or toward East Siberia where the international convention boundary would complicate the process of oil spill cleanup.

Oil spill drift in open water is generally estimated as the vector sum of the velocity and direction of all applicable currents and winds. The seasonal currents and circulation characteristics have been discussed in an earlier section and shown in figures 2, 3 and 4. Superimposed upon this mean circulation are weak tidal and usually stronger, locally generated wind-driven currents. These wind-driven currents can be about three to four percent of the wind velocity and, in the shallow shelf area of the Chukchi Sea, can quickly dominate other factors in oil spill drift. In response to severe storms and high pressure systems, storm surges may transport oil spills over intertidal zones or landfast ice onto environmentally sensitive Arctic ecosystems.

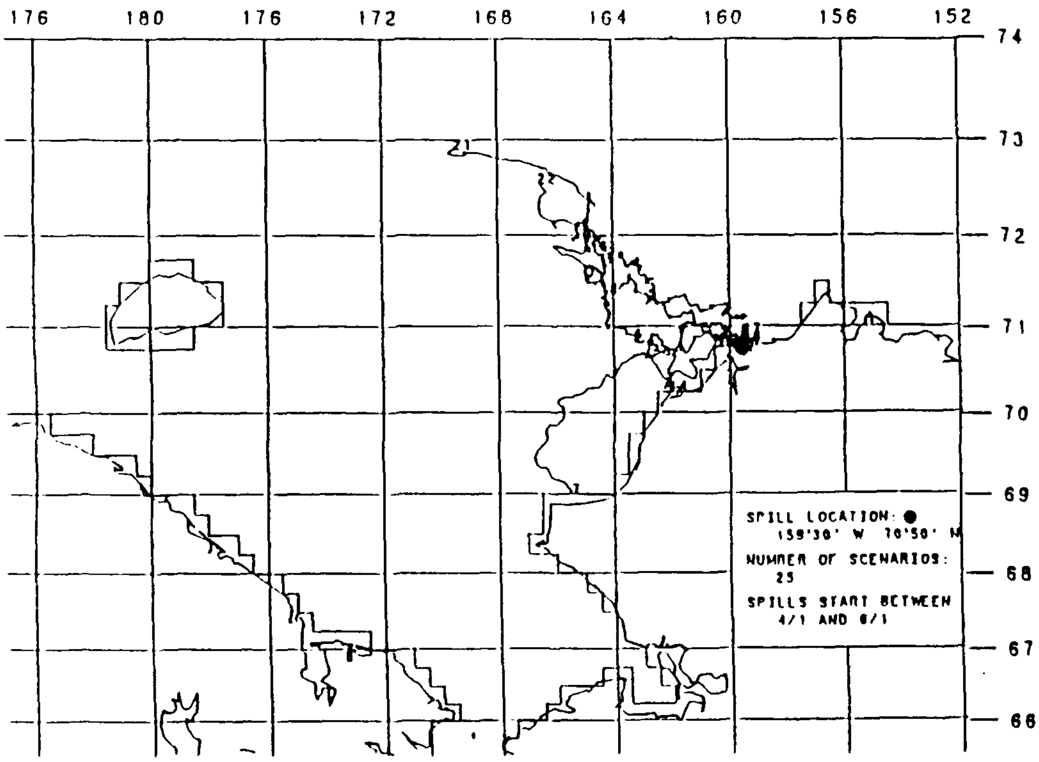
The greatest challenge in estimating the movement of an oil spill occurs when the oil enters ice infested water. The ice-oil spill scenario presents a much more complicated situation than with an open water spill, because the variability of the oil spill track is much higher due to the modifying effects of different types and extent of ice cover. Most of the oils likely to be spilled will float although some of the heavier oils will sink at low winter temperatures. Oil rising beneath sea ice will collect in depressions on the under surface of first year or landfast ice and may become oil-lenses contained in fresh ice. Oil flowing into pack and grease ice or the open leads and polynas that many migratory mammals depend on for passage through the Chukchi to the Beaufort or Bering Seas may be frozen in and encapsulated. This oil trapped in ice at the beginning of winter has the potential to travel hundreds of kilometers before melting forces in summer can release this fresh, unweathered, oil into potentially sensitive ecosystems. Brine-channels, appearing as first year ice melts, allow trapped oil to percolate to the surface early in the summer thaw. Oil trapped in multiyear ice with no brine channels can be transported long distances and for periods over one year. When oil is spilled on top of sea ice either through brine channels or blowouts, the oil absorbs incident solar radiation and melting is accelerated. Melt pools thus formed have a low reflectivity and further accelerate the melting process.

The information in the remainder of this atlas of oceanographic and climatological data for the Chukchi Sea is intended to give the OSC some readily available guidance in estimating the possible general fate of target oil spills.

OIL SPILL TRANSPORT



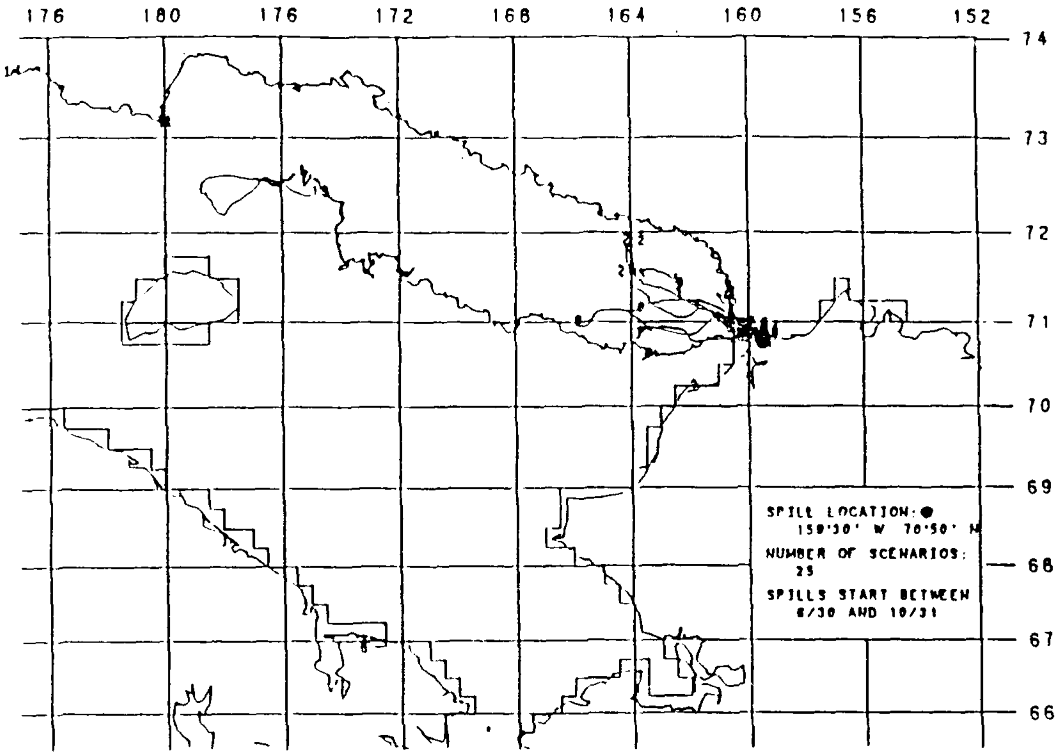
A. Cape Lisburne Area Spills March-August



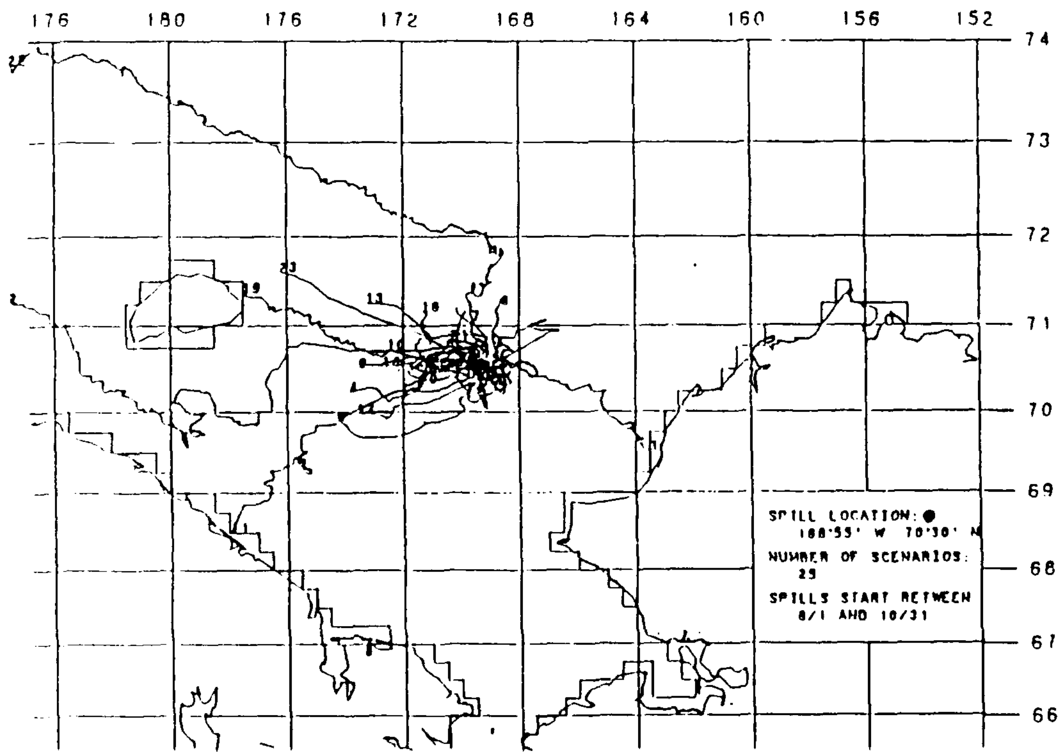
B. Wainwright Area Spills May-June

Figures 12a, 12b

OIL SPILL TRANSPORT



C. Wainwright Area Spills June-October



D. Mid-Chukchi Sea Area Spills August-October

Figures 12c, 12d

METEOROLOGY

SEASONAL WEATHER

Surface terrain features along the Chukchi Sea coast have strong local influence on weather patterns (Kozo 1980). The topography of the land adjacent to the Chukchi Sea is low plains except for the Brooks Range beginning at the coast near Cape Lisburne, Cape Mountain and high bluffs near Cape Prince of Wales, and low mountains and bluffs along parts of the Siberian Peninsula. These topographic features have different local effects on wind speed and direction depending also on the orientation of the atmospheric pressure gradient characterized much of the year by a strong capping inversion at 60 to 100m (Overland 1985).

A major influence on the general circulation of the area occurs through seasonal distribution of atmospheric pressure. There is a high pressure region which is normally located over the Beaufort Sea centered at about 79°N, 170°W during the winter and which pushes an easterly wind at Point Barrow and northeasterly offshore of Cape Lisburne and Tin City. There are mountain effects near Cape Lisburne so the vector mean wind is southeasterly.

During winter there is latitudinal variation in air temperature because of the latitudinal dependence of the length of solar day and the latitudinal dependence of occasional low pressure centers stemming from the Bering Sea (Pease 1987). These lows bring warm, moist air with periods of southeasterly wind and in winter rarely penetrate as far north as Point Barrow.

South and west of this so called Beaufort High, a Siberian high pressure system can form an occasional saddle pattern over the western Chukchi Sea when light winds occur. During summer, there is frequently a low pressure system at a similar location in the Beaufort or shifted more symmetrically over the pole (Colony and Munoz 1985).

In autumn as solar radiation decreases, the Chukchi Sea cools through net upward long-wave radiation and turbulent (sensible) heat flux to the atmosphere. Chukchi Sea ice-free coastal water reaches the freezing point at Point Barrow in late September and by early December in the Bering Strait. The monthly variability in meteorologic conditions is much higher than variability among years and is dependent on these regional atmospherics and the transport of heat by the barotropic current through the Bering Strait which is in turn locally wind-driven (Aagaard, et al. 1985).

STORM SURGES

Storm surges are waves oscillating in the period range of a few minutes to a few days, in a *near coastal or inland* water body, resulting from forcing from atmospheric weather systems (Murty 1984). By this definition, wind-generated waves (often referred to as wind waves) and swell, which have periods of several seconds, are excluded. The spectrum of storm surge waves is centered around 10^{-4} cycles per second (cps), which gives a period of about three hours. However, the periods of the water level oscillations may vary considerably, depending mainly on the topography of the water body and secondarily on other parameters such as the direction of movement of the storm, strength of the storm, stratification of the water body, presence or absence of ice cover, and nature of tidal motion in the water body. Even in the same water body, storm surge records at different locations can exhibit different periods. The range or height of a storm surge depends not only on characteristics of the storm but also on the topography onshore and bathymetry offshore. Shallow water bodies generally experience surges with greater ranges. Also, the height of a storm surge is less if the sea floor is steep than if there is a shallow slope to the sea floor (Murty 1984). Storm characteristics that effect the height of a surge include atmospheric pressure; wind speed, direction, and length of fetch; the latitude; and the direction and speed of storm movement. Air and water temperature differences also affect the height of surges.

The following paragraphs summarizing the storm surge potential for various areas of the Chukchi Sea coastline rely heavily on the work of Wise, Comiskey, and Becker (1981) and Brower et al. (1988) supplemented by storm statistics from NOAA Storm Data, 1981-1986.

The northern part of the Chukchi Sea coastline is generally of low relief, covered with numerous shallow lakes from Point Barrow to Point Lay. The onshore terrain becomes more rugged south to Cape Lisburne and Point Hope. The topography is very rugged at the west end of the Brooks Range. Offshore the ocean floor is gently sloping, except for the areas west of Point Hope and northwest of Point Barrow.

The area most susceptible to storm surge flooding is north from Point Lay. Nearshore, surface currents flow primarily toward the northeast, parallel to the coast. Strong southwest storm winds tend to accelerate this current causing a net transport of surface water to the right toward the coast. Storms moving from the west or southwest can develop sufficient fetch for surges up to 3m (10 ft) during the ice-free period from July to October. Shorefast ice forms along the entire coast in late October and early November, and ice also forms over the open sea, thereby diminishing the occurrence of storm surges. Known cases of storm surge flooding have been from August to about mid-October. A surge up to 3.5m (11 ft) occurred at Barrow in October 1983 and was judged to be a 124-year event. For the most part, surges of 2 to 3m are considered to be 10-year events (Lewbel and Gallaway 1984).

The north shore of Kotzebue Sound is of moderate relief, becoming less rugged to the east and south. Offshore the sound is generally shallow, less than 20m with the exception of a deeper channel offshore from Cape Espenberg, at the entrance to the sound. These conditions are favorable for the development of storm surges. Most storm surges occur in latesummer and fall. From November to May the sound is generally ice-covered, which reduces the effects

of storm surges. However, there have been several occurrences of flooding on top of the shorefast ice in the area. Storm tracks from surge-causing storms can be either from the south (from Bering Sea to southern Chukchi Sea) or from the northwest (from the open water north of Siberia to Kotzebue Sound). See figure 13.

Onshore topography for the northwest coast of the Seward Peninsula is generally of low relief. A string of barrier islands lies offshore. Offshore bathymetry has variable slope, with the 20m isobath anywhere from 5 to 25 miles offshore. Prevailing ocean currents are generally parallel to the coast near shore. Southwest winds in the eastern quadrant of storms moving northward tend to accelerate this current, causing beach erosion as well as storm surge. Storm surges and beach erosion are, for the most part, limited to the ice-free season from June to November.

To assess whether storm surges might be an important factor in the movement of an oil spill, the following manual surge height forecast procedure was adapted from Wise, Comiskey, and Becker (1981). Surge height versus wind speed from Sector 2, Sectors 3, 4, and 5, and Sectors 7 and 8 was plotted and followed the curve shown in figure 14. This curve provides some of the manual input to the following procedure.

Storm Tracks for Storm Surges

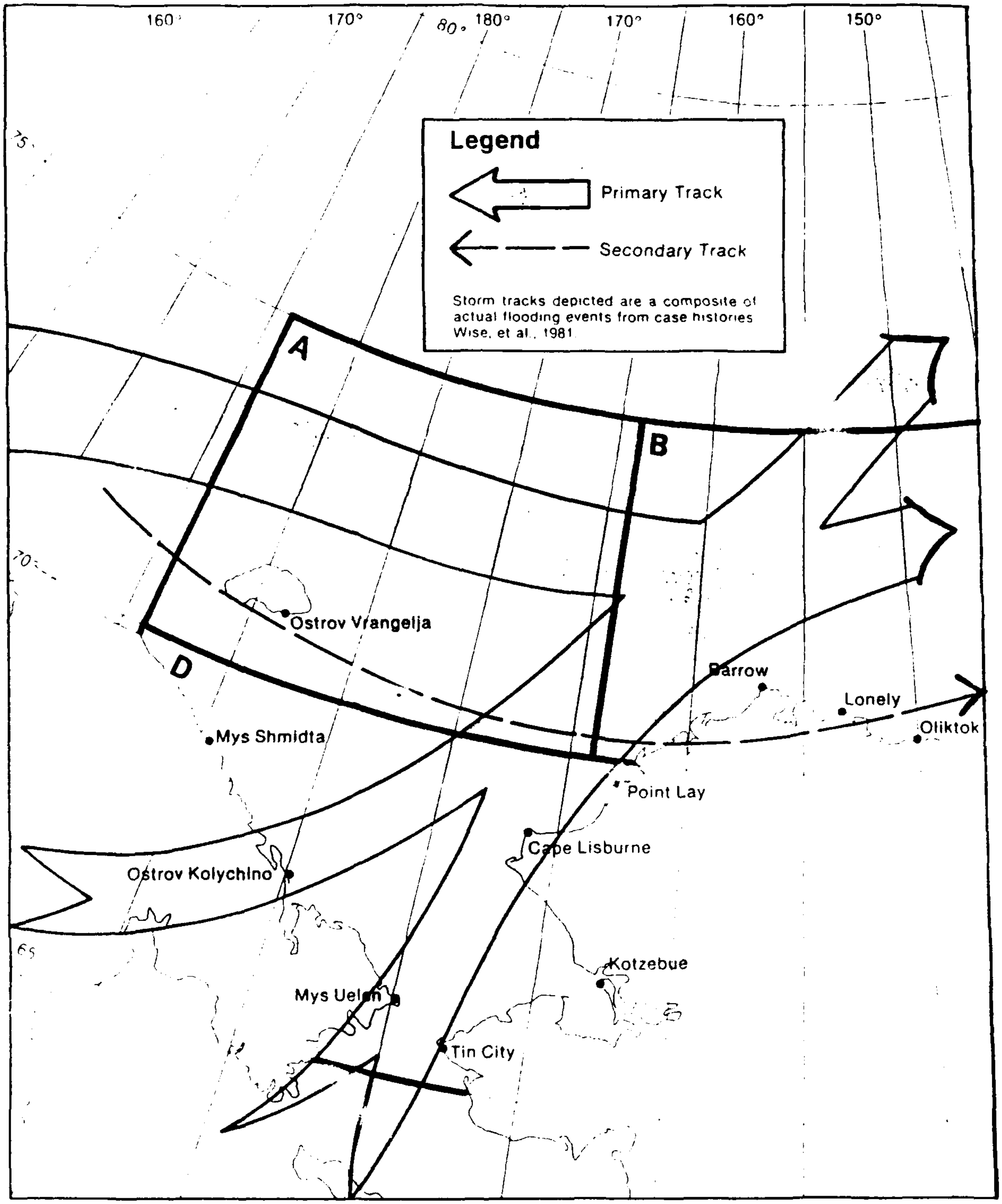


Figure 13

Manual Forecast Procedures

I. Definitions

A. SURGE - the height of the ocean's surface above forecast (tidal) levels.

B. FAVORABLE RELATIVE FETCH WIND DIRECTION - Assume the coastal configuration to be straight line segments as shown on figure 15, Coastal Sectors for Storm Surge Forecasting. When facing seaward, the relative wind direction is measured clockwise from the coast. Thus the coast to the left is 0°; seaward +090°; to the right 180°. If offshore, values are from 0°-180° measured counterclockwise from left coast. Favorable relative wind directions are:

SECTOR	FAVORABLE	DIRECTION	
2	-020	to	090
3	080	to	140
4	010	to	050
5	-050	to	-010
6	040	to	090
7	020	to	090

In an idealized model, the most favorable directions are from -020 to 090 but topography working in conjunction with gravity acting on anomalous sea surface slopes creates surges (generally of lesser magnitude) in areas wherein the wind is not blowing from an idealized "favorable" direction. The favorable directions shown above are those relative directions where the wind creates an anomalous sea height somewhere nearby that, in turn, affects the sector of interest.

C. FETCH - An area in which wind direction and speed are reasonably constant and do not vary past the following limits:

(1) The wind direction or orientation of the isobars does not change direction at a rate greater than 15° per 180 nmi and the total changes do not exceed 30°.

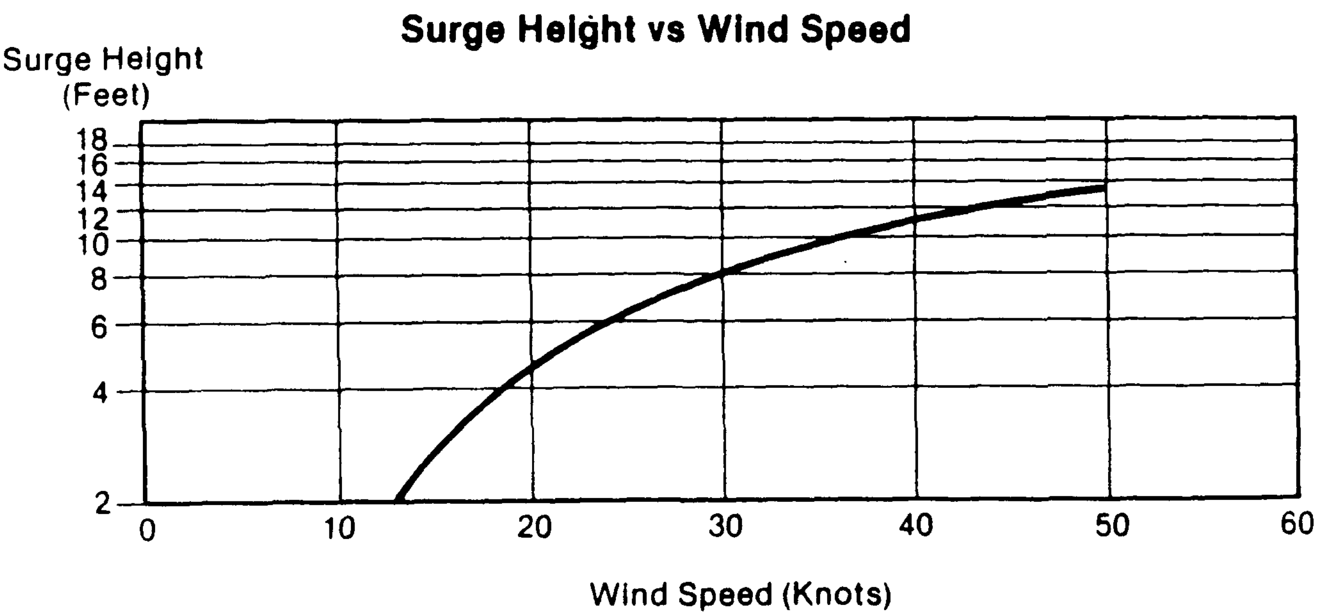


Figure 14

Coastal Sectors for Storm Surge Forecasting

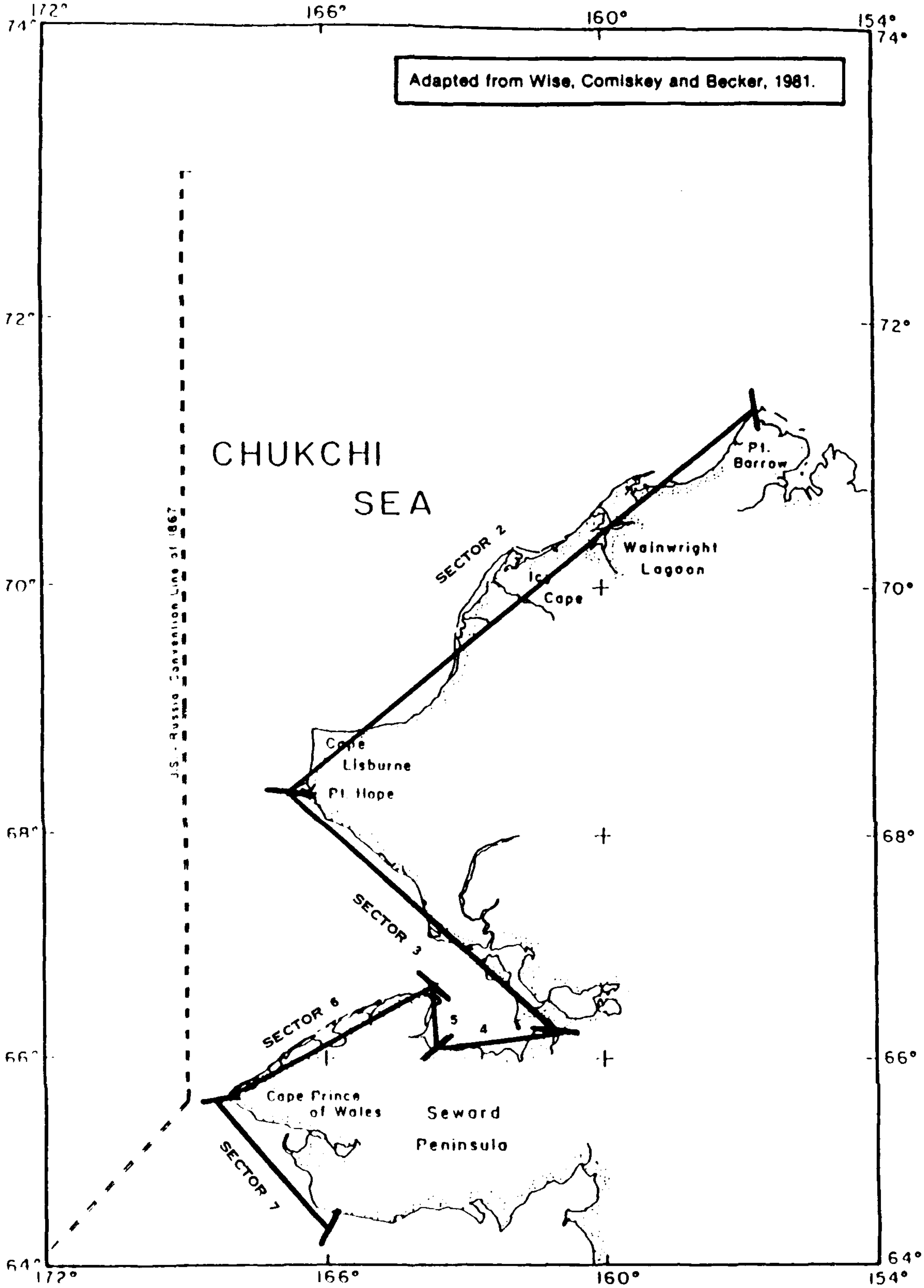


Figure 15

(2) The wind speed does not vary more than 20% from the average wind speed. Example: average wind is 4000, acceptable range is 32 to 48.

D. FETCH DURATION - the number of hours a coastal area is subjected to fetch winds.

E. LOWEST PRESSURE - The lowest pressure coincident with fetch induced surge.

F. SEA ICE COVERAGE (minimum expected during storm) - Percent of sea ice coverage in tenths.

G. SEA ICE CHARACTER - Primary concern is thinness and weakness. Thin or unconsolidated ice can be destroyed by storm action.

H. BOUNDARY LAYER STABILITY - The difference between the sea and air temperatures. The boundary layer temperature difference should be used when estimating the fetch wind speed. The following guidelines are suggested:

Correction to Geostrophic Wind for the Sea-Air Temperature Difference

$T_s - T_a$ °C	Percent of geostrophic winds used
0 or negative	50
0 to 10	55
10 to 20	60
20 or above	65

II. Procedure

A. Determine:

(1) Fetch wind (speed and direction) from a surface map analysis of pressure gradient and reported wind. Consider boundary layer conditions. If direction is favorable continue with determination of:

(a) fetch duration
(b) ice cover
(c) lowest pressure
(d) tidal variation if over 1 ft

B. Preliminary Surge Height - Using wind speed, read correlated surge height from appropriate coordinate labels in figure 14, surge height vs. wind speed.

C. Duration Adjusted Surge Height - If fetch duration is less than:

(1) 3 hours reduce surge by 60%
(2) 6 hours reduce surge by 40%
(3) 9 hours reduce surge by 20%
(4) 12 hours reduce surge by 10%
(5) 12+ hours no reduction

D. Ice Cover Adjusted Surge Height - If ice cover is less than:

(1) 1.5 tenths no reduction
(2) 3.0 tenths reduce surge by 20% (cumulative to above)
(3) 5.0 tenths reduce surge by 50% (cumulative)
(4) 10.0 tenths reduce surge by 75% (cumulative)

E. Pressure Adjusted Surge Height - Raise the surge height one foot for every 30 mb pressure increment below 1004 mb.

F. Tidal Adjusted Surge Height - Check tide tables or other sources. Forecast time of highest range based on loss of favorable wind direction, speed, or fetch. If peak of surge time is reasonably coincident with normal high water, make no correction. If surge misses normal high water, subtract as appropriate from surge height.

III. Example

A possible surge condition is developing in sector 4. Fetch wind is southwest 35 kts. Relative wind direction is 035, a favorable direction for sector 4. Preliminary surge height is 10 ft (figure 14). Duration is 10 hours. Reduce surge 10% (10 - 1 = 9). Ice cover is 2 tenths. Reduce surge 20% (9.0 - 1.8 = 7.2). Lowest pressure coincident with surge is 964 mb. Raise surge height 1.3 ft (7.2 + 1.3 = 8.5). Time of high water is coincident with time of surge, no correction. Final surge height forecast is 8.5 ft.

The above surge reductions were subjectively derived and may be adjusted with time and experience.

SUPERSTRUCTURE ICING

Structural icing on ships, offshore structures, and port facilities is a wintertime hazard in open waters and coastal sections of Alaska. The icing causes slippery decks, renders moving parts inoperable, and, in extreme cases, causes uneven loading and raises the center of gravity on small ships. Accumulation of ice on rigging and on deck equipment such as crab pots also increases wind effects because a larger surface area is presented to the wind. Ice forming on structural surfaces above or close to a body of water arises principally from sea spray (Nauman and Tyagi 1985; Liljestrom 1985), with lesser amounts from atmospheric precipitation (freezing rain and wet snow) and fog (arctic sea smoke, white frost, black frost). Sea spray, the most dangerous source of icing, is produced by the breaking of waves against obstacles such as ships' hulls, other floating objects, shore structures, and, possibly, other sources (Minsk 1977).

Statistical analysis (Borisenkov and Panov 1972) of more than 3,000 cases of ship icing indicates that in 86% of the cases icing was caused by ocean spray alone. Spray combined with fog, rain, or drizzle (liquid sources) accounted for only 6.4% of the cases, and spray combined with (solid source) snow only 1.1%. The cases of icing attributable only to fog, rain, or drizzle account for 2.7% (Minsk 1977). In the remainder of icing cases data were not sufficient to determine the cause.

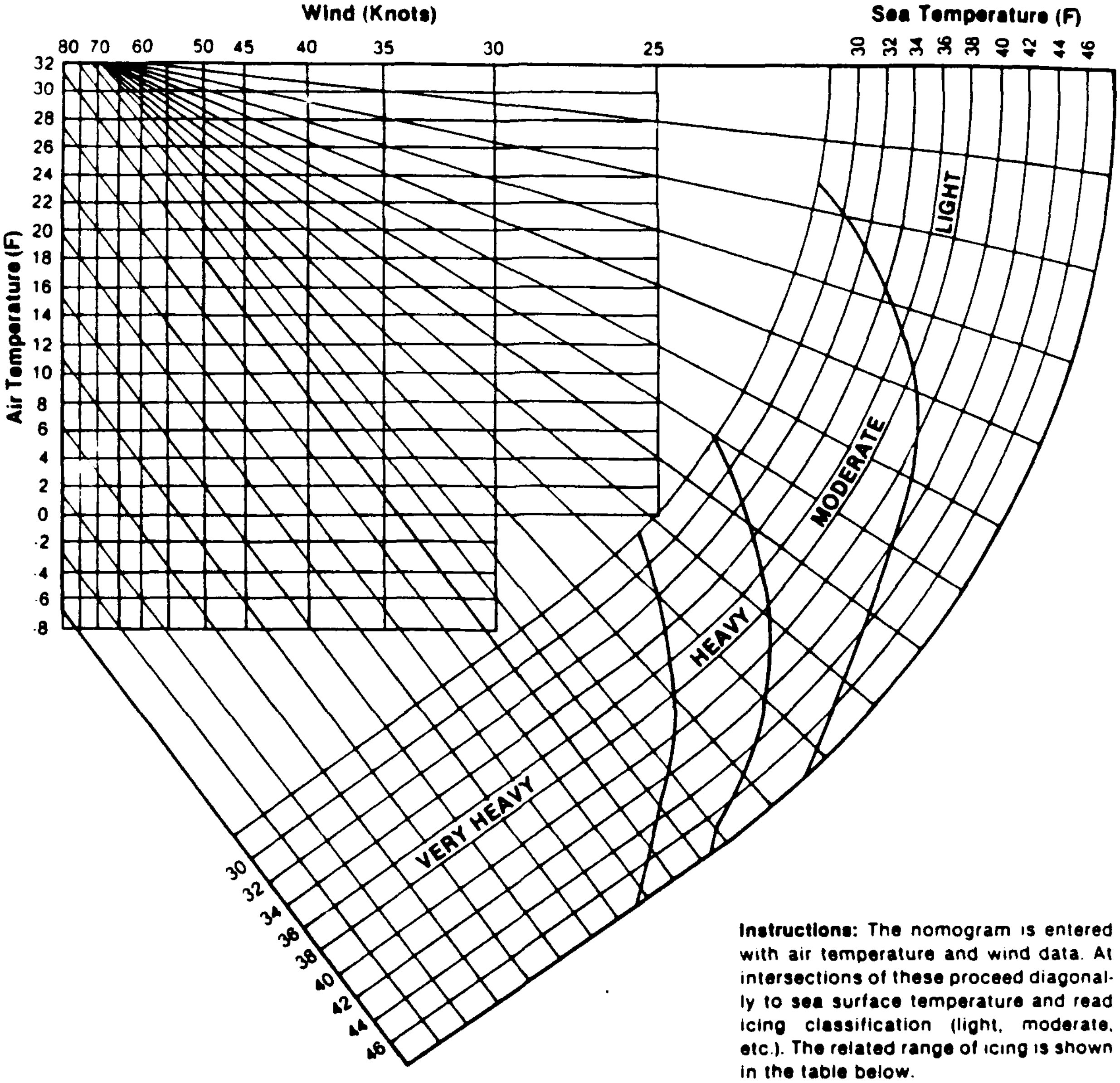
Since the overwhelming majority of superstructure icing on ships and offshore structures is from sea spray, the remainder of this section will concentrate on this type of icing. Since a ship can present different aspects to the wind and spray, it is to be expected that the amount of spray reaching the ship will vary: Russian observations (Brower et al. 1988) showed that the greatest frequency of spray and, therefore, icing occurs when a ship is heading into the wind at an angle between 15° and 45°. Asymmetrical icing occurs under this conditions, with the greater accumulation on the windward side. Less icing occurs with the ship headed directly into the wind, and then accumulation tends to be uniform. With ships heading downwind, spray icing is generally much less than at other angles. In developing the *nomogram for forecasting* spray icing potential, downwind cases (those for which the ship's heading was 120° or greater off the wind) were not used.

Meteorological/ oceanographic conditions necessary for significant spray icing are water temperatures less than 8°C, winds of 25 knots (13 meters per second) or more, and air temperatures less than -2°C (28°F, the freezing temperature of seawater of average salinity). Generally, the stronger the wind, and the colder the air and water, the higher the rate of icing on comparable vessels or structures. In some cases, however, where the wind fetch is not sufficient to fully develop waves, icing rates are lower.

The *accompanying potential superstructure* icing rate nomogram (figure 16) is a modification of that shown in Wise and Comiskey (1980), using the open ocean cases appearing in Pease and Comiskey (1985), developed from icing case histories in the Gulf of Alaska and southern Bering Sea. Icing intensities in inches per hour are also from Pease and Comiskey (1985). If a vessel experiencing icing takes evasive action (i.e., changes heading, reduces speed, seeks shelter, etc.), icing rates experienced would probably be less. The potential superstructure icing rate nomogram (figure 16) was developed from icing case histories in the Gulf of Alaska and southern Bering Sea. There is no comparable set of case histories of icing north of the Bering Strait.

Kozo (1985), in assessing the possible occurrence of superstructure icing in the Chukchi Sea, shows no chance of spray icing in the Chukchi Sea or, presumably, the Beaufort Sea from December through April because the

Superstructure Icing Nomogram



Instructions: The nomogram is entered with air temperature and wind data. At intersections of these proceed diagonally to sea surface temperature and read icing classification (light, moderate, etc.). The related range of icing is shown in the table below.

Icing Classification	Rate per Hour
Light	0 to .3 inches
Moderate	.3 to .8 inches
Heavy	.8 to 2 inches
Very Heavy	2 inches

Adapted from Wise and Comiskey, 1980, using data from Pease and Comiskey, 1985.

Figure 16

entire area is covered with sea ice during those months. In May, moderate to heavy icing is possible just north of the Bering Strait under conditions of minimum sea ice extent, minimum air temperature, and winds over 28 knots. The possibility of moderate to heavy superstructure icing spreads northward in the Chukchi Sea to 72°N, with minimum sea ice, in June. In July, the air temperatures are too warm for more than light to moderate superstructure icing over all the area, except near the pack ice edge. Under extreme conditions of minimum ice and minimum air temperature, moderate to heavy icing may occur north of 70°N. In August, as air temperatures begin to cool off in the the Beaufort and northern Chukchi Seas, the possibility of moderate icing increases under extreme conditions of minimum air temperatures and pack ice extent, and winds of 28 to 50 knots. In September, the area in which possible heavy superstructure icing is greatest extends from the pack ice edge south to Cape Lisburne and the Siberian coast. Light to moderate icing is possible south to the Bering strait under extreme conditions. By October and November, the seasonal advance of the pack ice limits the possibility of icing of all intensities to the Chukchi Sea.

WIND CHILL

(Equivalent Temperatures)

The temperature of the air is not always a reliable indicator of how cold a person will feel outdoors. Other weather elements, such as wind speed, relative humidity, and sunshine (solar radiation), also exert an influence. In addition, the type of clothing worn, together with the state of health and the metabolism of an individual, influence how cold a person will feel. Cooling may be described as loss of heat from exposed flesh. Freezing occurs when there is such total heat loss that ice forms in the exposed tissues. The cooling power of the atmosphere (by wind) is primarily heat transfer by advection in human cases, by exposure of uncovered flesh to the environment. Even small amounts of air movement have considerable chilling effect because this movement disrupts or removes the thin layer of warmed air that builds up near and about the body. This air movement leads to loss of total heat, since heat is transferred from the core of the body to rewarm the new colder air, replacing that blown away. Therefore, wind chill not only leads to frostbite locally, but may contribute to general hypothermia.

During the antarctic winter of 1941 Siple and Passel developed a formula to determine wind chill from experiments made at Little America (Siple and Passel 1945). The formula relates heat loss (H) from an object or person to wind speed and to the difference in temperature between the air and the object or person (ΔT). The skin temperature of most people is approximately 33°C (91.4°F). H is measured in heat units (calories) per unit area over time. Heat losses for the human body can then be computed for any combination of wind and temperature. Equivalent temperature is based on calm conditions and a person walking vigorously at 3 knots (4 mph). Each combination of wind and air temperature produces a heat loss (H). The equivalent temperature is that temperature that would compute the same heat loss at a wind of 3 knots. The accompanying chart (figure 17) shows equivalent wind chill temperatures in °C for various combinations of winds in knots or km/hr and temperatures.

Concepts in the following discussion of wind chill are from an appendix to an article by William J. Mills, Jr., M.D., as published in *Alaska Medicine* (1973). Dr. Mills is still active in the treatment of cold injuries in Alaska.

Almost everyone knows that the increased speed of wind may cause increased danger of skin freezing. Many assume that the increase in wind speed causes the ambient air temperature to fall lower. This is not so. What does occur is air movement, so that warmed air is moved away from the individual exposed to the wind, causing first local, then general body cooling. Any resultant decrease of skin temperature is due to heat loss, insidious or sudden. Local vasoconstriction, vascular shunting, and cellular changes take place; eventually ice forms in the tissues, with true tissue freezing or frostbite.

Wind chill may occur not only from natural wind, but also with air movement generated by a moving vehicle such as boats, aircraft, or helicopter rotoblades. These vehicles may predispose passengers to frostbite or general hypothermia. Equivalent temperatures of -30°C (-33°F) or colder are considered to severely limit outdoor activity. The maps which follow (figures 19a-19l) in the climatology section on temperature show the percent of time that wind chill of -30°C (-22°F) occurs in the Chukchi Sea area (Brower et al. 1988).

Equivalent Wind Chill Temperature

Wind Speed		Cooling Power Of Wind Expressed As "Equivalent Chill Temperature"																		
knots	km/hr	Temperature (°C)																		
Calm		12	8	4	0	-4	-8	-12	-16	-20	-24	-28	-32	-36	-40	-44	-48	-52	-56	-60
		Equivalent Chill Temperature																		
3	6	12	8	4	0	-4	-8	-12	-16	-20	-24	-28	-32	-36	-40	-44	-48	-52	-56	-60
5	10	9	5	0	-4	-8	-13	-17	-22	-26	-31	-36	-40	-44	-49	-53	-58	-62	-67	-71
11	20	5	0	-5	-10	-15	-21	-26	-31	-36	-42	-47	-52	-57	-63	-68	-73	-78	-84	-89
16	30	3	-3	-8	-14	-20	-25	-31	-37	-43	-48	-54	-60	-65	-71	-77	-82	-88	-94	-99
22	40	1	-5	-11	-17	-23	-29	-36	-41	-47	-53	-59	-65	-71	-77	-83	-89	-95	-101	-107
27	50	0	-6	-12	-18	-25	-31	-37	-43	-49	-56	-62	-68	-74	-80	-87	-93	-99	-105	-112
32	60	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-70	-77	-83	-89	-96	-102	-109	-115
38	70	-1	-7	-14	-20	-27	-33	-40	-46	-52	-59	-65	-72	-78	-85	-91	-98	-104	-111	-117
43	80	-1	-8	-14	-21	-27	-34	-40	-47	-53	-60	-66	-73	-79	-86	-92	-99	-105	-112	-118
49	90	-1	-8	-14	-21	-27	-34	-40	-47	-53	-60	-66	-73	-79	-86	-92	-99	-105	-112	-118
54	100	-1	-8	-14	-21	-27	-34	-40	-47	-53	-60	-66	-73	-79	-86	-92	-99	-105	-112	-118
		Little Danger					Increasing Danger (Flesh May Freeze Within 1 Minute)				Great Danger (Flesh May Freeze Within 30 Seconds)									
Danger of Freezing Exposed Flesh For Properly Clothed Individuals																				

Adapted from NWS/NOAA Technical Procedures Bulletin No. 165
Effective Temperature (Wind Chill Index) 1976

Figure 17

CLIMATOLOGY

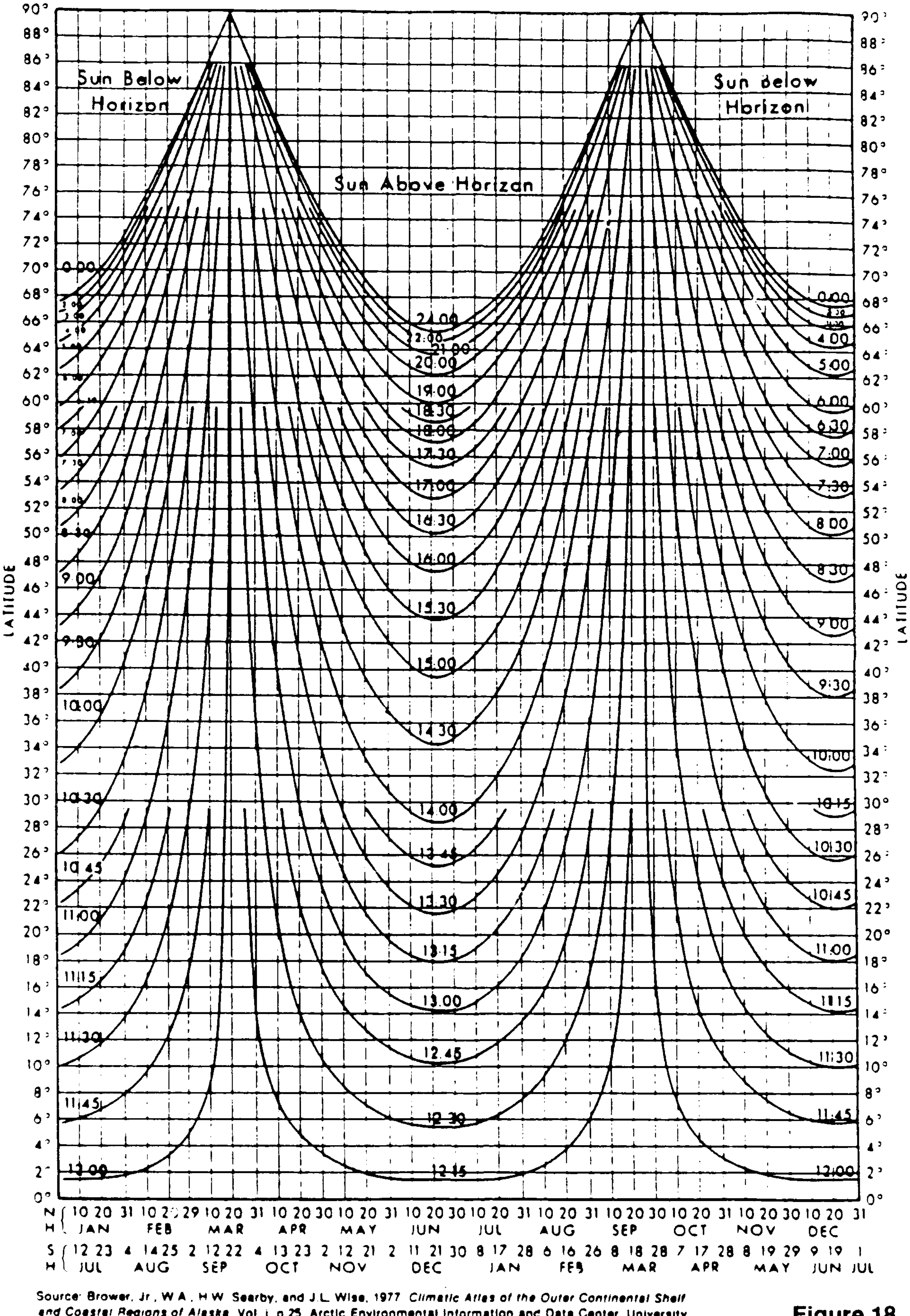
INTRODUCTION

The Chukchi Sea yearly climatic cycle consists of a long, cold winter followed by a few weeks of spring thaw, and a short, cool summer followed by a few weeks of fall freeze. Local climatic conditions are influenced by regional topography especially the varied elevation of the Brooks Range. The Chukchi Sea and the northern Bering Sea span the transition between polar oceanic climate typical of the central Bering Sea and high-contrast polar climate typical of the Beaufort Sea. A polar region is a geographic region with a mean monthly air temperature for the warmest month of less than 10°C. The polar oceanic climate has the additional constraint of high annual precipitation (>0.3m) that is nearly uniformly distributed through the seasons. A high-contrast polar climate has lower total precipitation and larger seasonal variability in temperature and precipitation (Overland 1981).

The Chukchi Sea is characterized by varied and extreme climate depending on season and location. Table 3 adapted from Brower et al. (1988), shows the climatic mean and extremes for several of the land stations in the Chukchi Sea. The overall low air temperatures, low total precipitation and snowfall, and variable wind speed/direction as well as the modifying influence of capes, mountains, and latitude are shown among the land stations. Because of the locational and seasonal variability over this large Chukchi Sea study area, the data in this section are depicted in the form of isopleth maps and graphs from many specific reporting stations or areas. Graphed data are for land stations (Ostrov Vrangelja, Mys Shmidta, Ostrov Kolychino, Mys Uelen, Tin City, Kotzebue, Cape Lisburne, Point Lay, Barrow) and for three marine areas A (70-75°N, 164-184°W), B (70-75°N, 144-164°W) and D (65-70°N, 164-184°W), which includes the entire area of interest plus some additional area to the west. Isopleth maps cover the appropriate portion of the three marine areas. Note also that the vertical scale on the graphs varies considerably from one location to another and by time of year. There is considerably more data for the land stations than the marine areas because land stations have more observations per day than ships. Also ship traffic is not possible for most of the winter months which reduces the marine area data for this season.

Figure 18 is a graph of the duration-of-daylight for the northern hemisphere and defines daylight as the period from sunrise to sunset. Additional light (during twilight) may be usable for many purposes. Duration of daylight in the entire study area becomes increasingly dependent upon atmospheric conditions and refraction which may cause some departure from the values depicted on the chart. The high latitude and low sun angle for the Chukchi Sea study area produce high net radiational heat loss. The high surface albedo typical of persistent snow and ice cover reflects much of the incident solar radiation and adds to the maintenance of low air temperatures. These low temperatures and restricted atmospheric exchange produce a stable stratified air mass around the pole. Frontal systems, where warmer, low-latitude air masses and colder polar air mix, move eastward around the pole.

Duration of Daylight (Hours)



Source: Brower, Jr., W.A., H.W. Searby, and J.L. Wise, 1977. *Climatic Atlas of the Outer Continental Shelf and Coastal Regions of Alaska*. Vol. I, p 25. Arctic Environmental Information and Data Center, University of Alaska, Anchorage and U.S. National Climatic Center, Asheville, NC. 3 vols.

Figure 18

TEMPERATURE

The air temperature in the Chukchi Sea shows both extreme seasonal and geographical (latitudinal) variability which is most effectively described by isopleth maps or graphs for different months and locations.

Figures 19a-19l show the mean air temperature (°C) and percent frequency of air temperatures under 0°C (32°F).

Figures 20a-20l show the monthly air temperature extremes.

Figures 21a-21l show the monthly air temperature/wind speed data indicating the percent frequency that a given air temperature occurs coincidentally with a given wind speed.

Figures 22a-22l show the air temperature/wind direction charts indicating the percent frequency that a given air temperature occurs coincidentally with a given wind direction.

Table 3. Climatic Means and Extremes for Personnel and Equipment measured at several Land Stations in the Chukchi Sea

Climatic Means and Extremes	Tin City	Shishmaref	Kotzebue	Cape Lisburne	Point Lay	Wainwright	Point Barrow
Temperature (°C)							
Mean Annual Maximum	-3.9	-2.9	-2.6	-5.6	-7.1	-8.4	-9.8
Mean Annual Minimum	-8.7	-9.9	-9.8	-10.4	-14.4	-15.1	-15.7
Highest	23.3	25.6	29.4	23.3	25.6	26.7	25.6
Lowest	-40.6	-44.4	-46.7	-43.9	-48.3	-48.9	-48.9
Total Precipitation (Inches)							
Average Annual	12.08	8.05	8.53	11.41	6.58	5.75	4.75
Greatest Month	5.79	4.36	5.18	6.98	6.24	9.29	2.81
Greatest Day	1.93	1.80	1.78	1.84	1.54	4.00	1.00
Snowfall (Inches)							
Average Annual	54.7	31.9	45.5	41.9	20.9	17.4	27.9
Greatest Month	34.4	20.3	23.9	35.5	9.9	11.8	21.2
Greatest Day	8.6	NA	10.0	12.0	3.0	4.0	15.0
Snow Depth (Inches)							
Annual Maximum	34	21	53	45	24	15	30
Surface Winds (knots)							
Prevailing Direction	N	NA	E	E	ENE	E	E
Average Annual Speed	15.4	NA	13.0	9.4	10.4	8.7	11.8
Fastest Direction	SSE	NA	E	SSE	NA	NA	SW
Maximum Speed	70	NA	72	80	NA	NA	60

Mean Air Temperature & Frequency ≤ 0°C

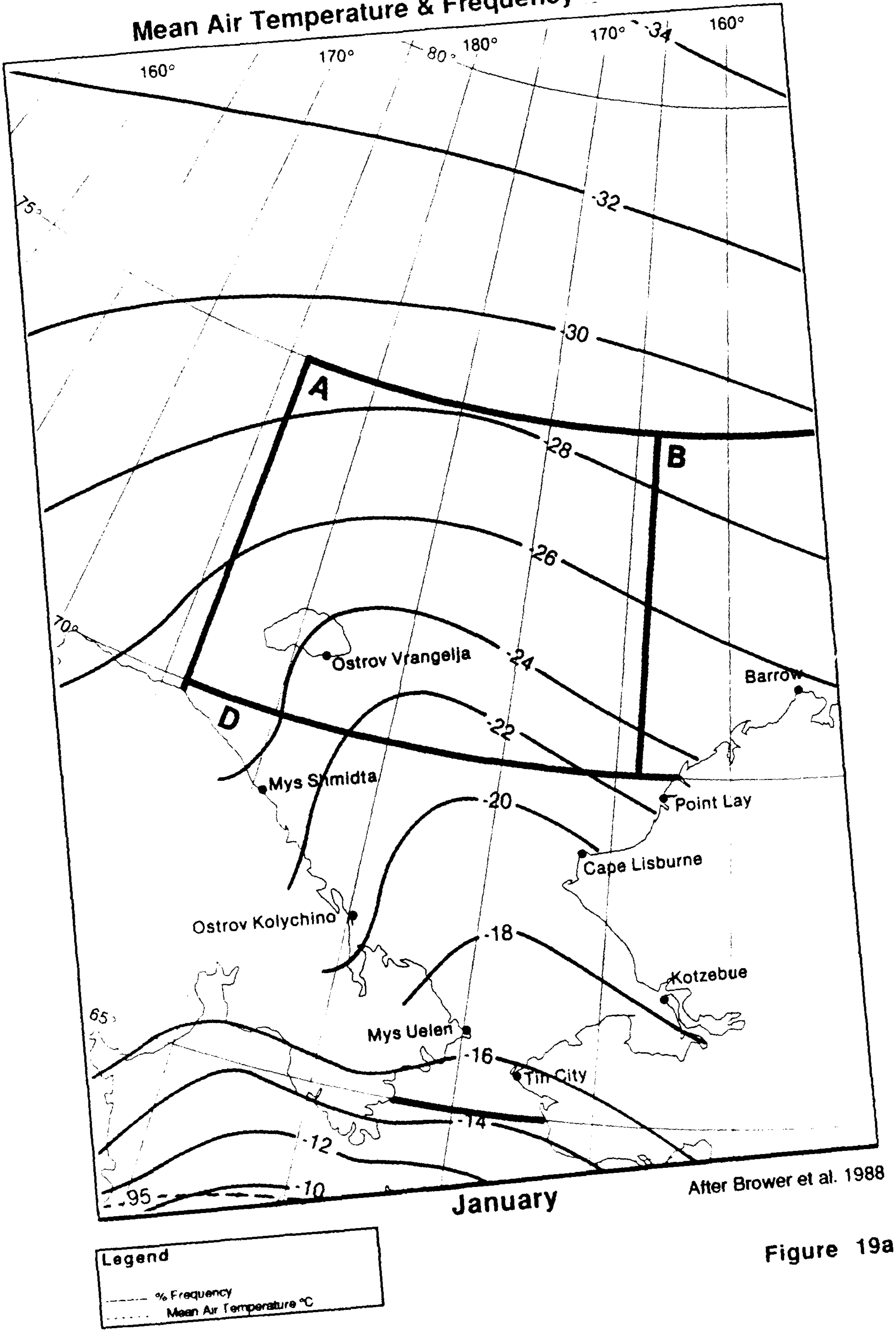
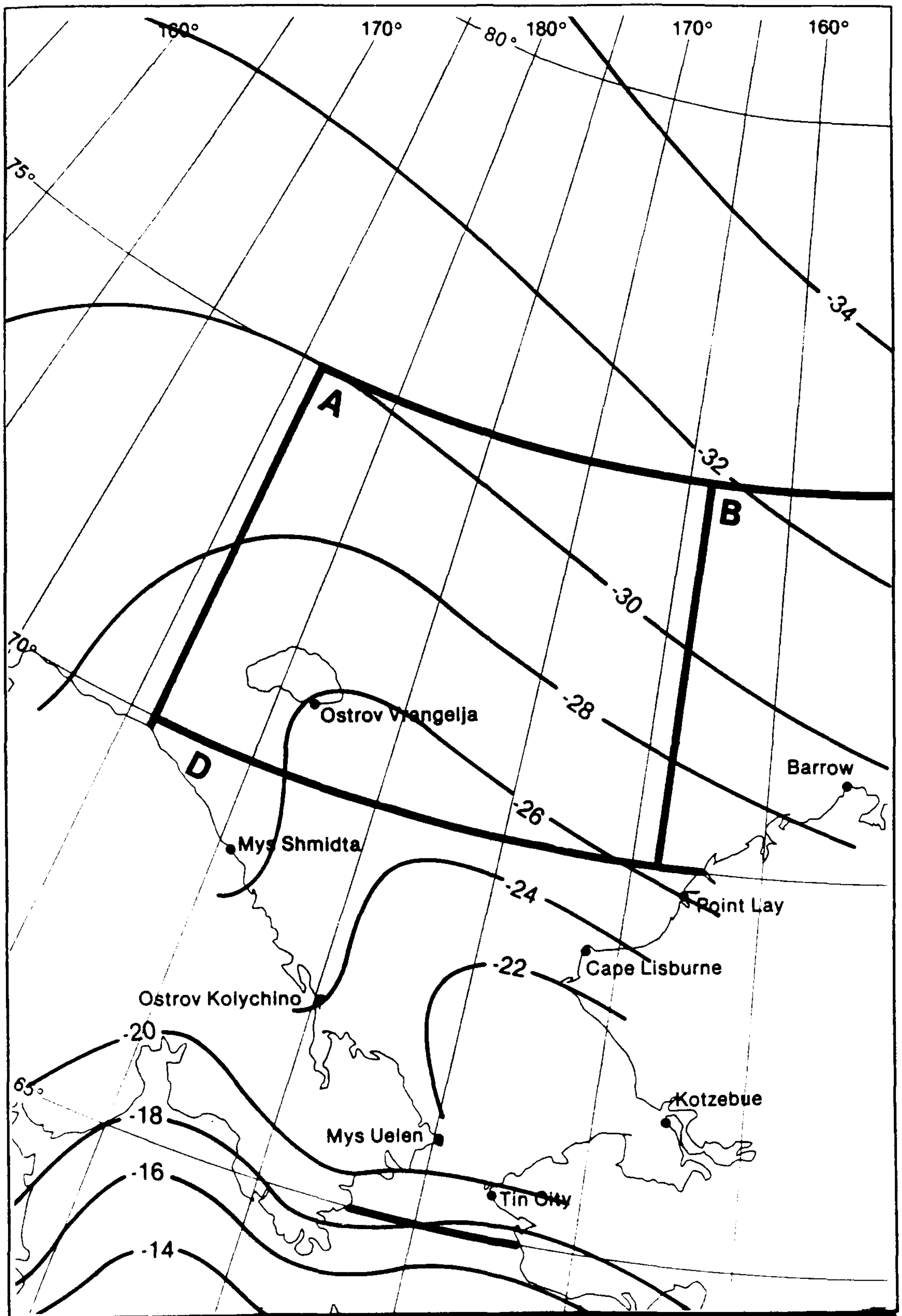


Figure 19a

Mean Air Temperature & Frequency < 0°C



February

After Brower et al. 1988

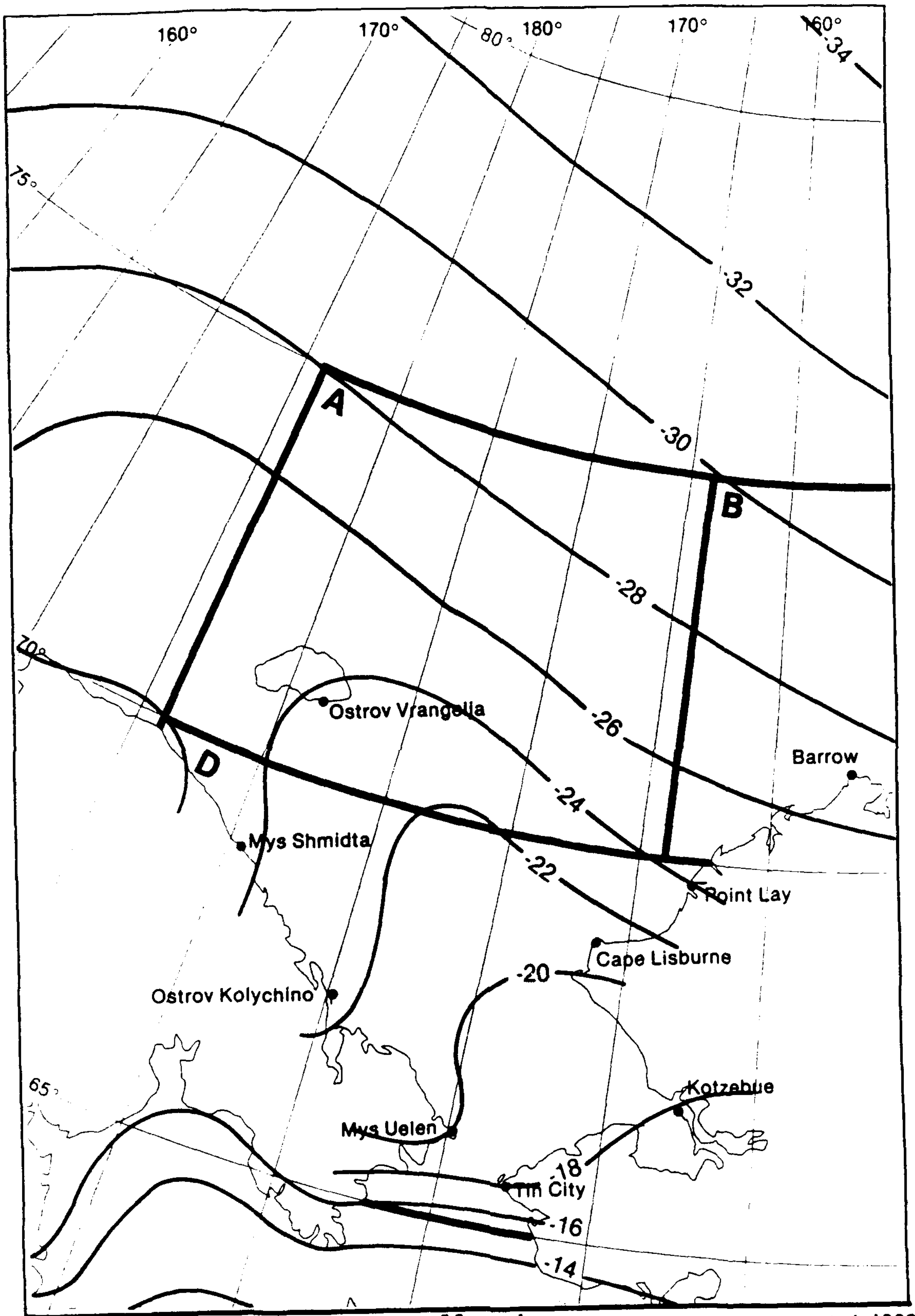
Legend

------ % Frequency

- - - - - Mean Air Temperature °C

Figure 19b

Mean Air Temperature & Frequency ≤ 0°C



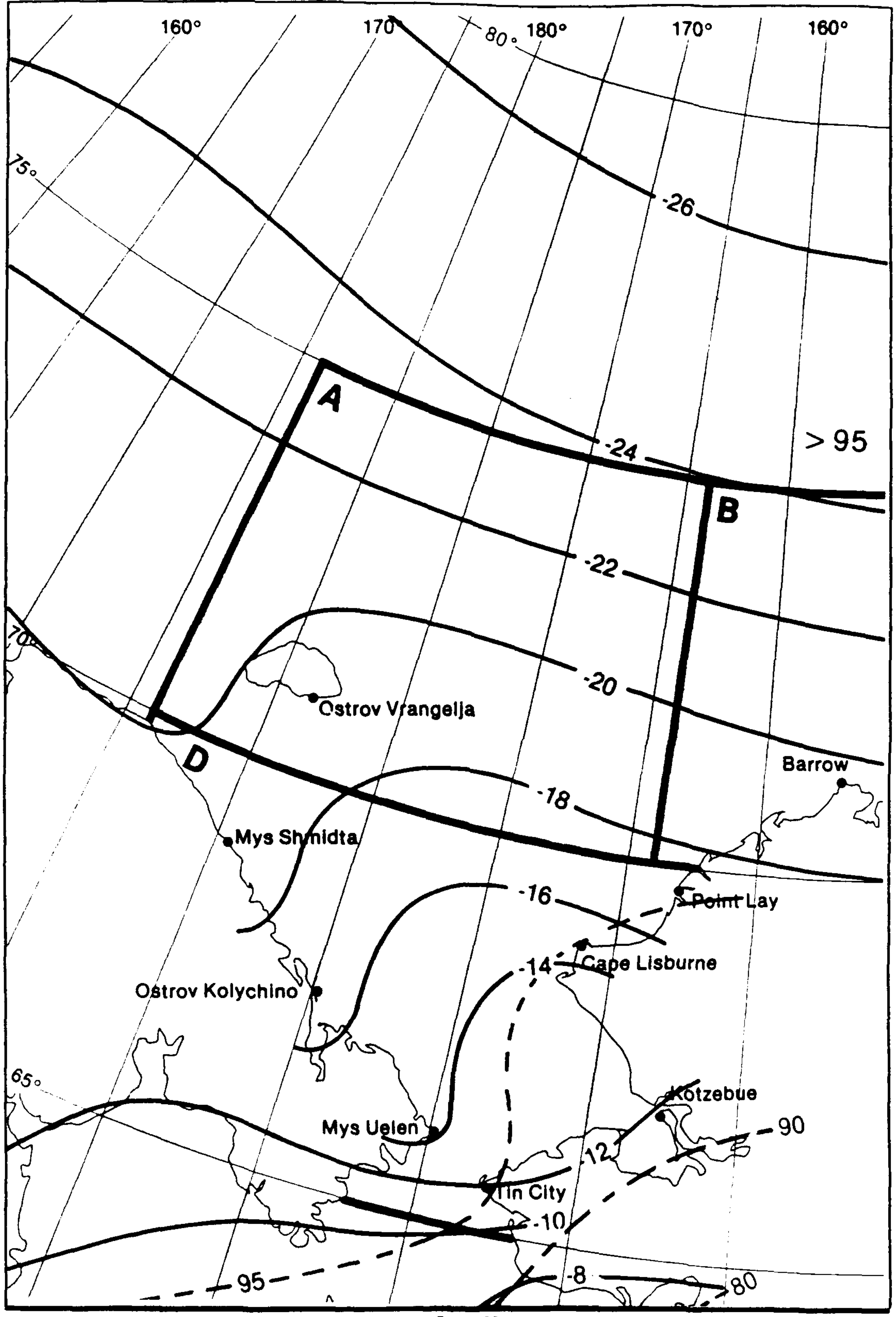
March

After Brower et al. 1988

Legend	
------	% Frequency
- - - - - -	Mean Air Temperature °C

Figure 19c

Mean Air Temperature & Frequency ≤ 0°C



April

After Brower et al. 1988

Legend

------ % Frequency
- - - - - Mean Air Temperature °C

Figure 19d

Mean Air Temperature & Frequency ≤ 0°C

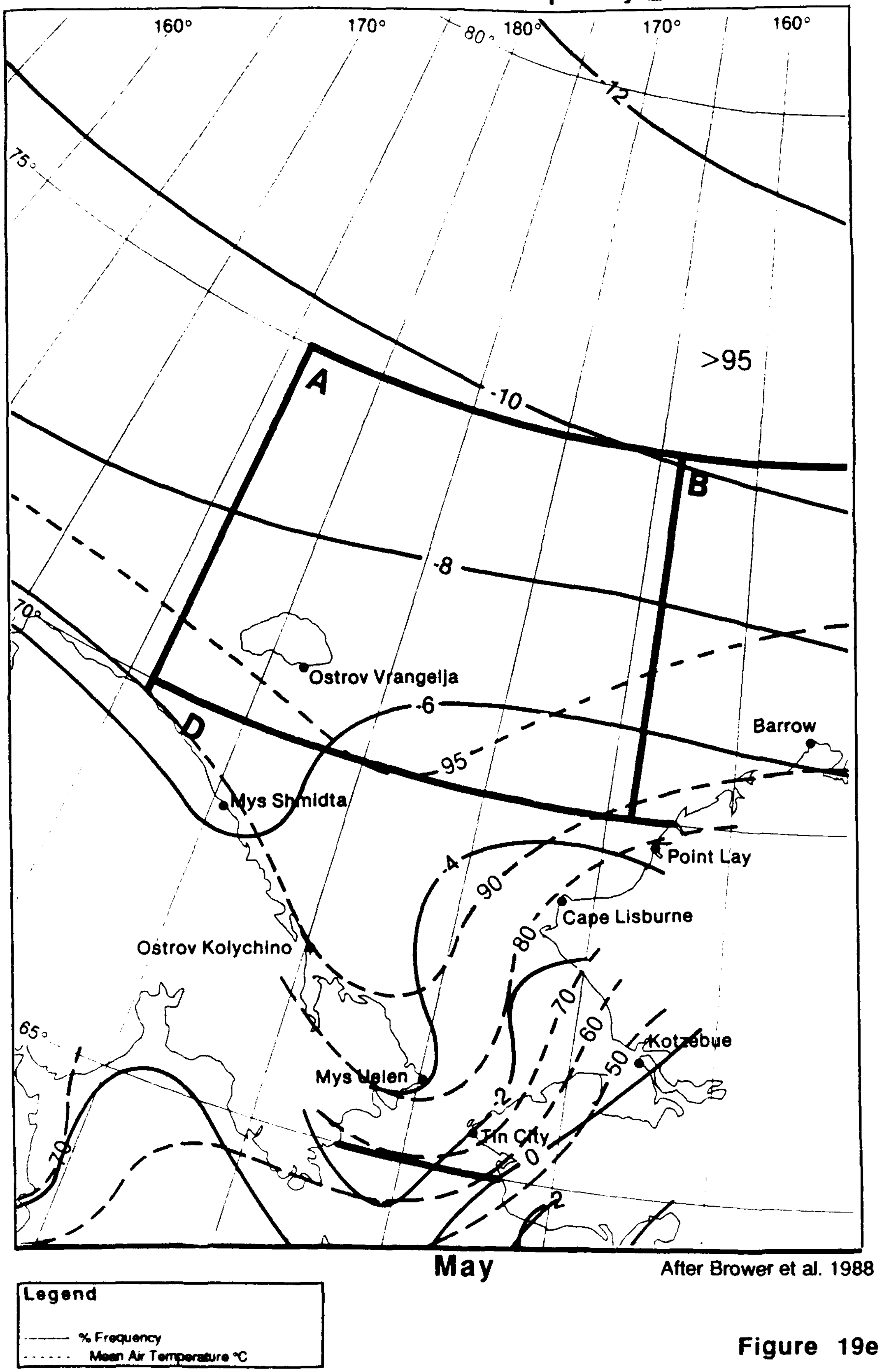
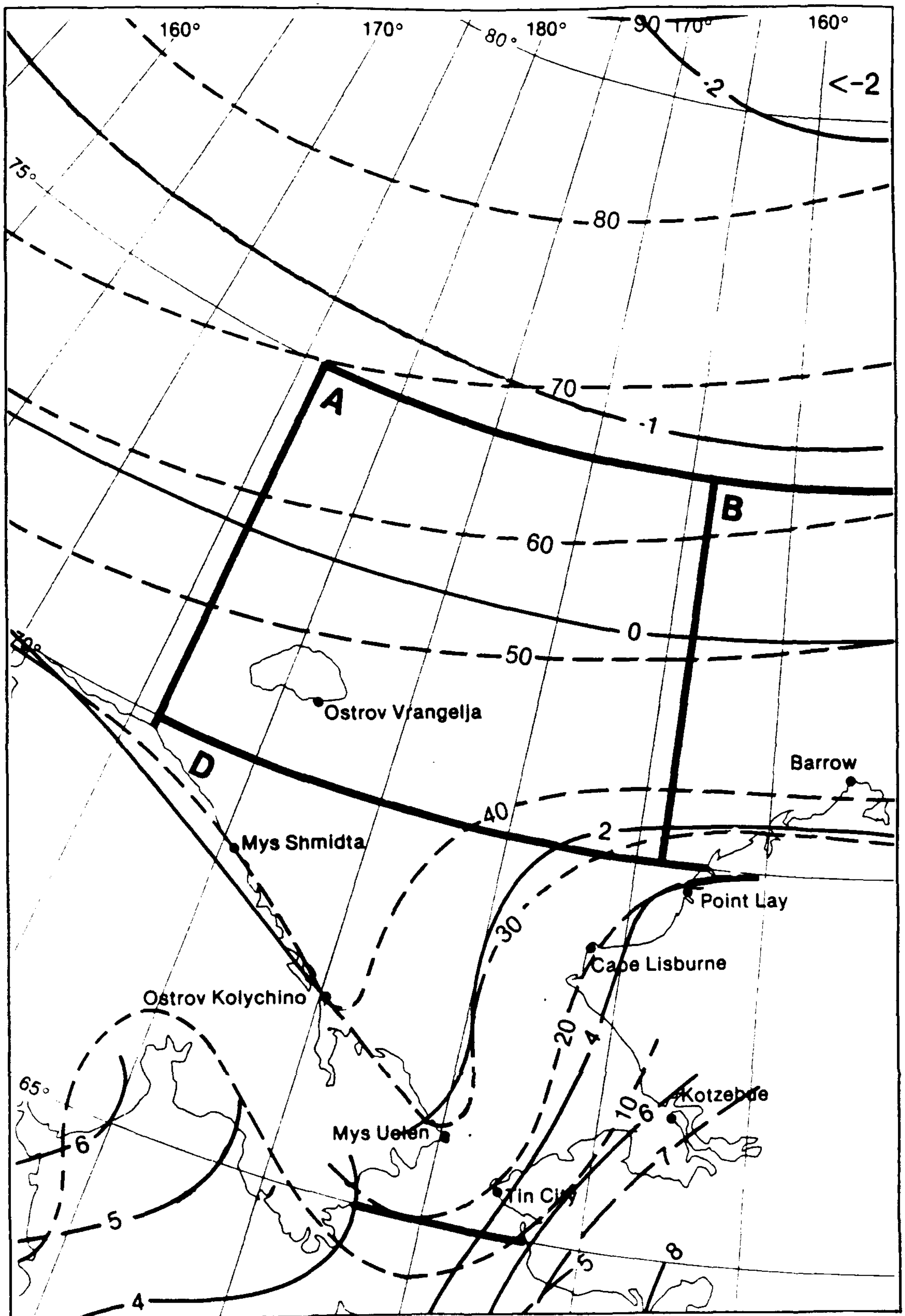


Figure 19e

Mean Air Temperature & Frequency < 0°C



June

After Brower et al. 1988

Legend
------ % Frequency
· · · · · · Mean Air Temperature °C

Figure 19f

Mean Air Temperature & Frequency ≤ 0°C

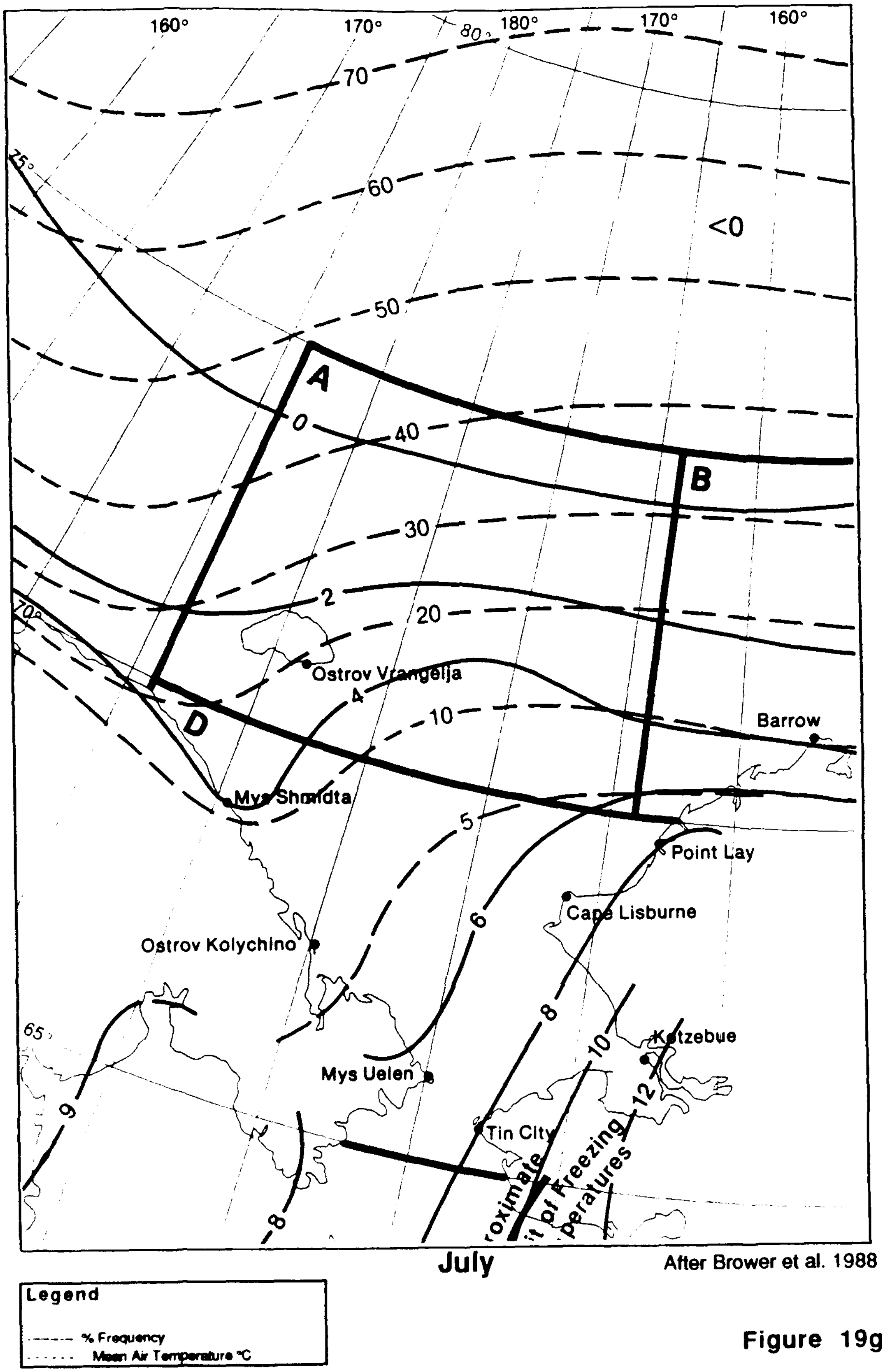
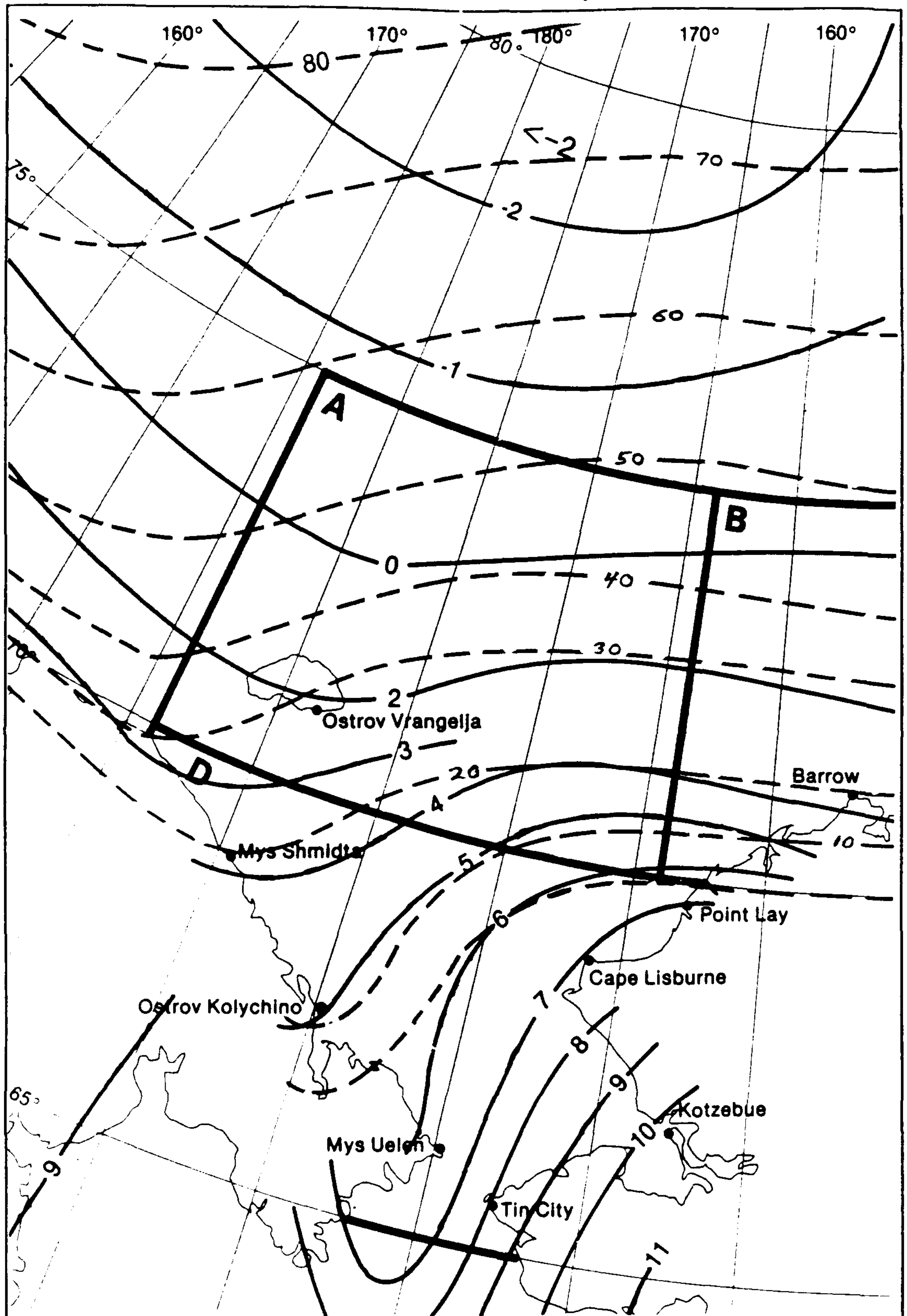


Figure 19g

Mean Air Temperature & Frequency ≤ 0°C



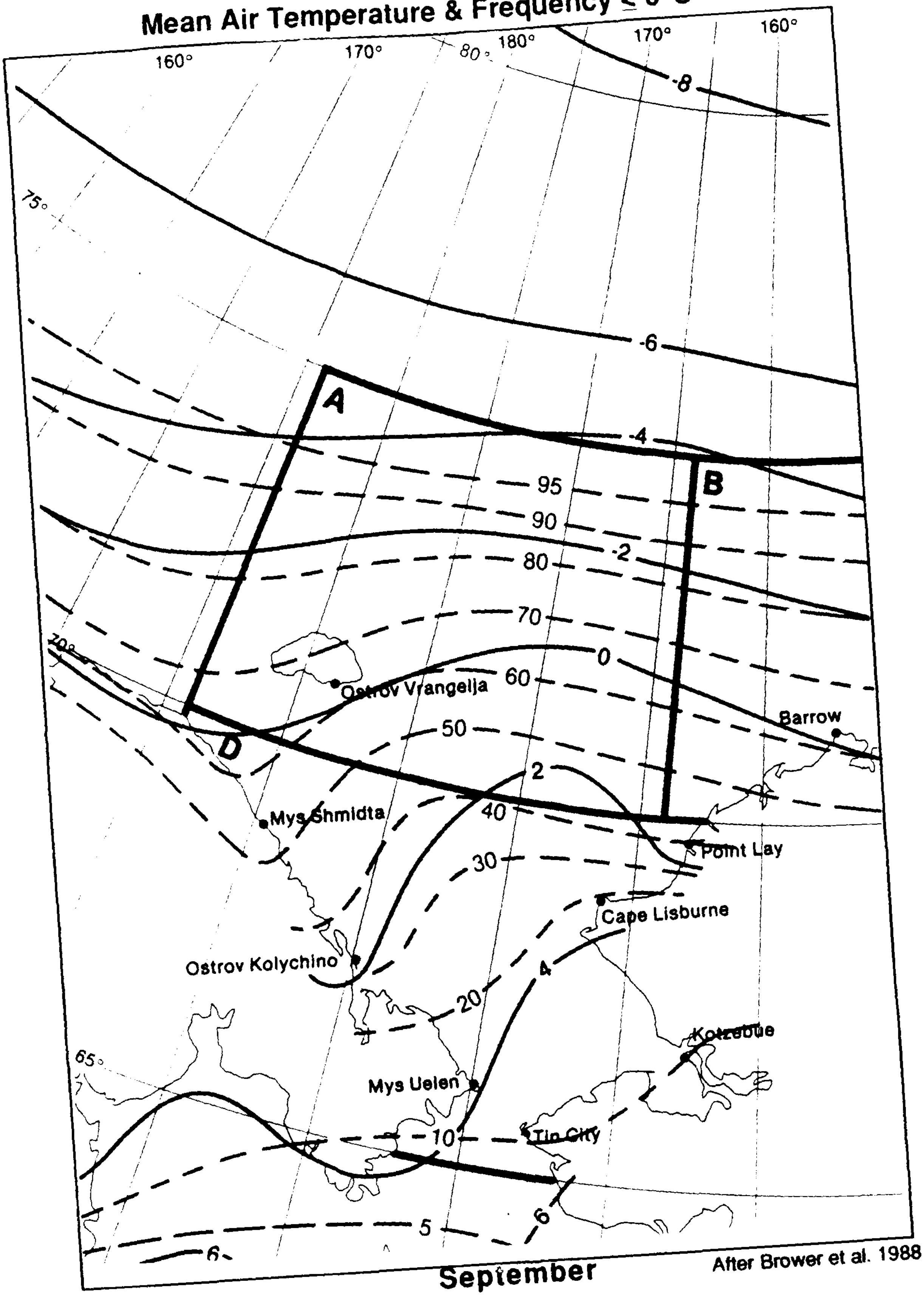
August

After Brower et al. 1988

Legend	
-------	% Frequency
- - - - -	Mean Air Temperature °C

Figure 19h

Mean Air Temperature & Frequency ≤ 0°C



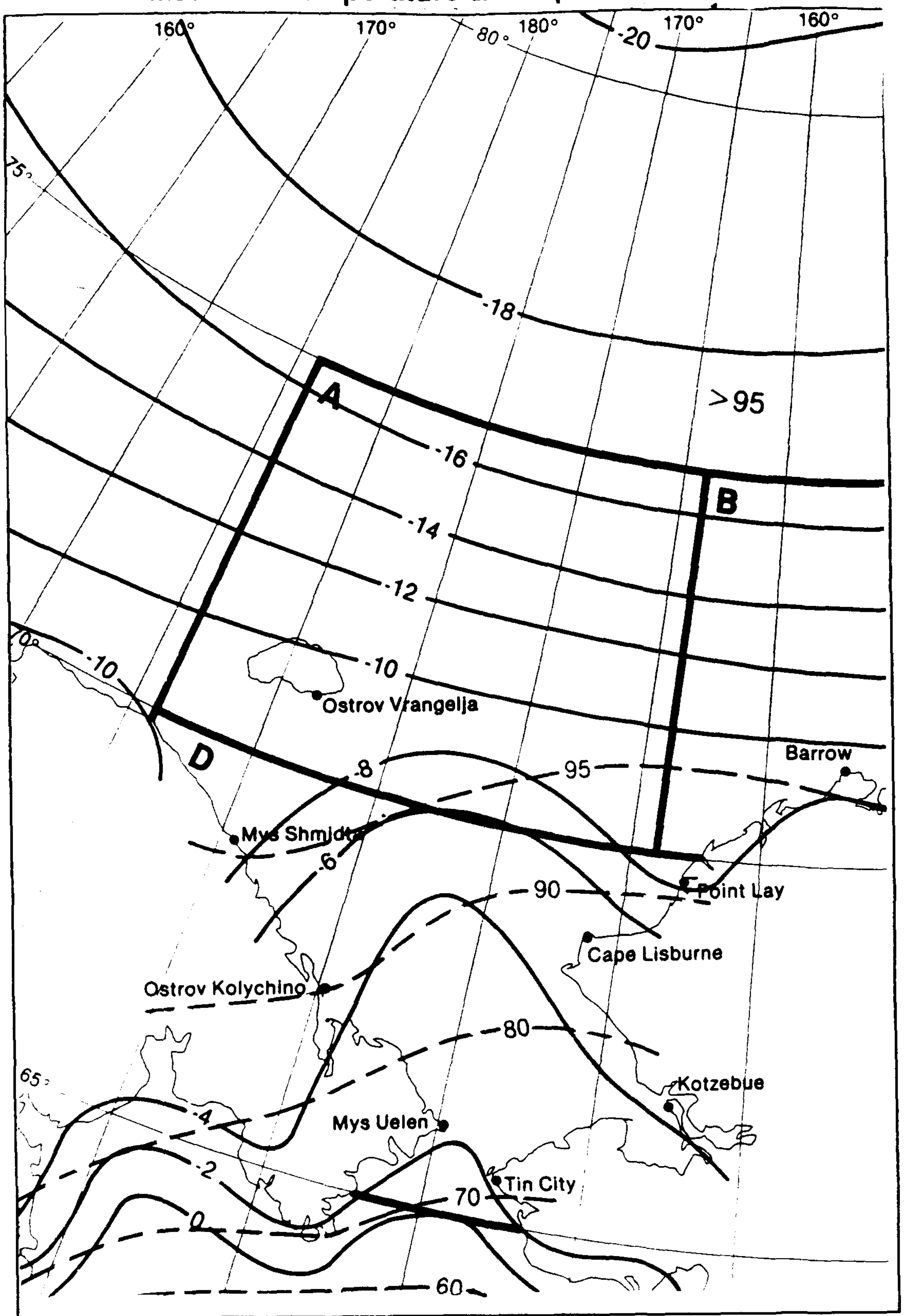
September

After Brower et al. 1988

Legend
- % Frequency
- Mean Air Temperature °C

Figure 19i

Mean Air Temperature & Frequency ≤ 0°C

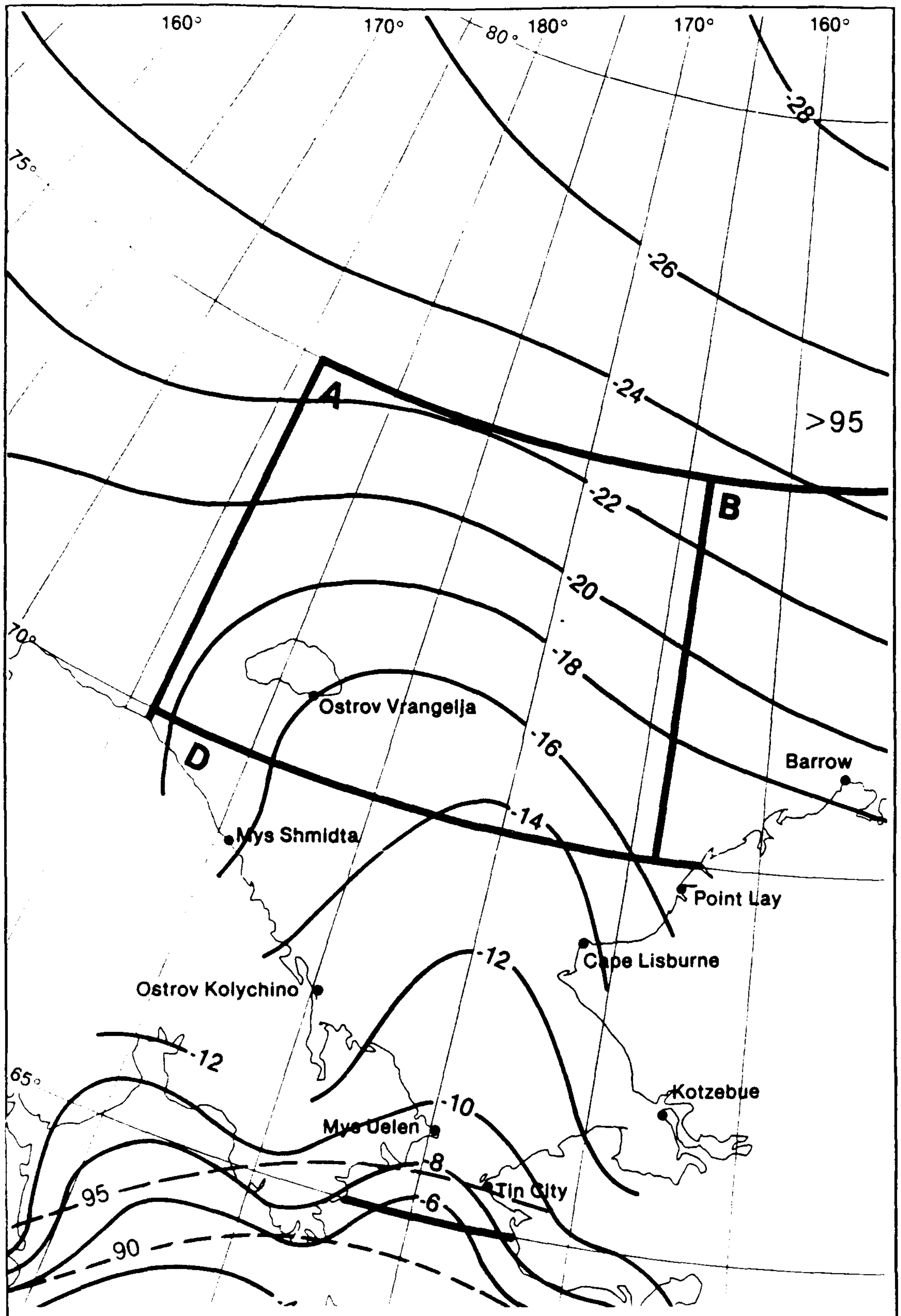


After Brower et al. 1988

Legend
------ % Frequency
. . . . . . Mean Air Temperature °C

Figure 19j

Mean Air Temperature & Frequency ≤ 0°C



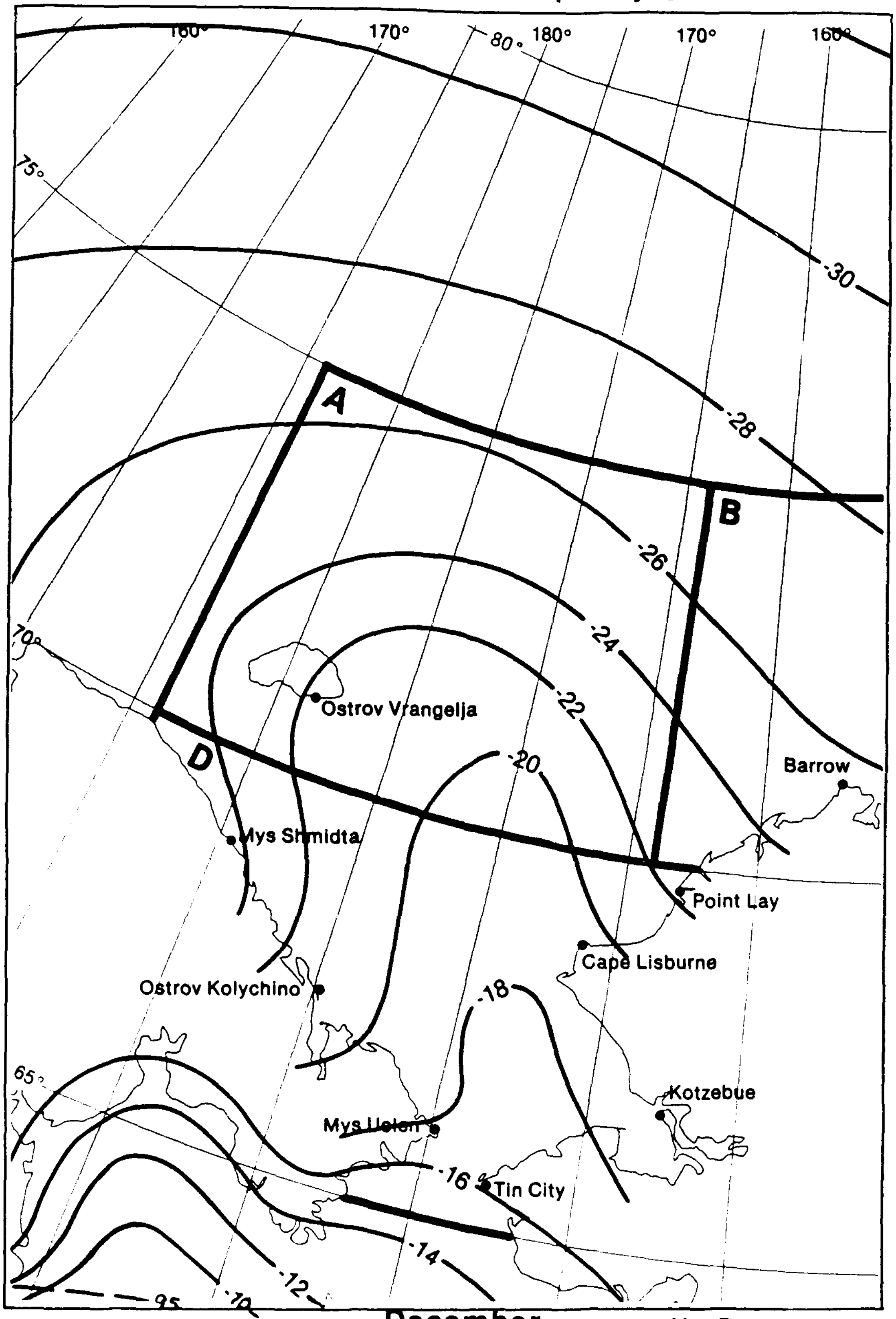
November

After Brower et al. 1988

Legend
------- % Frequency
- - - - - - Mean Air Temperature °C

Figure 19k

Mean Air Temperature & Frequency ≤ 0°C



December

After Brower et al. 1988

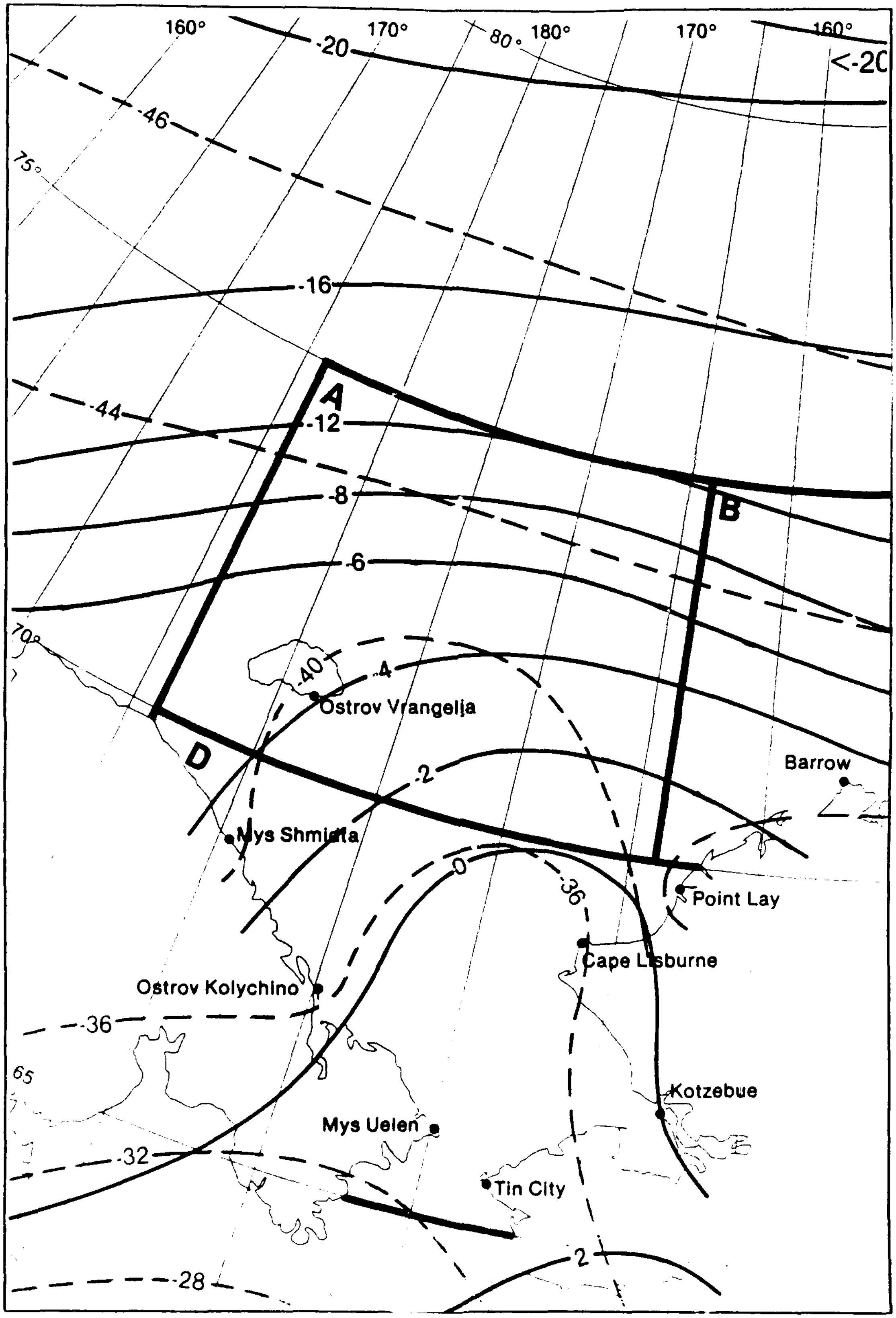
Legend

% Frequency

Mean Air Temperature °C

Figure 191

Air Temperature Extremes



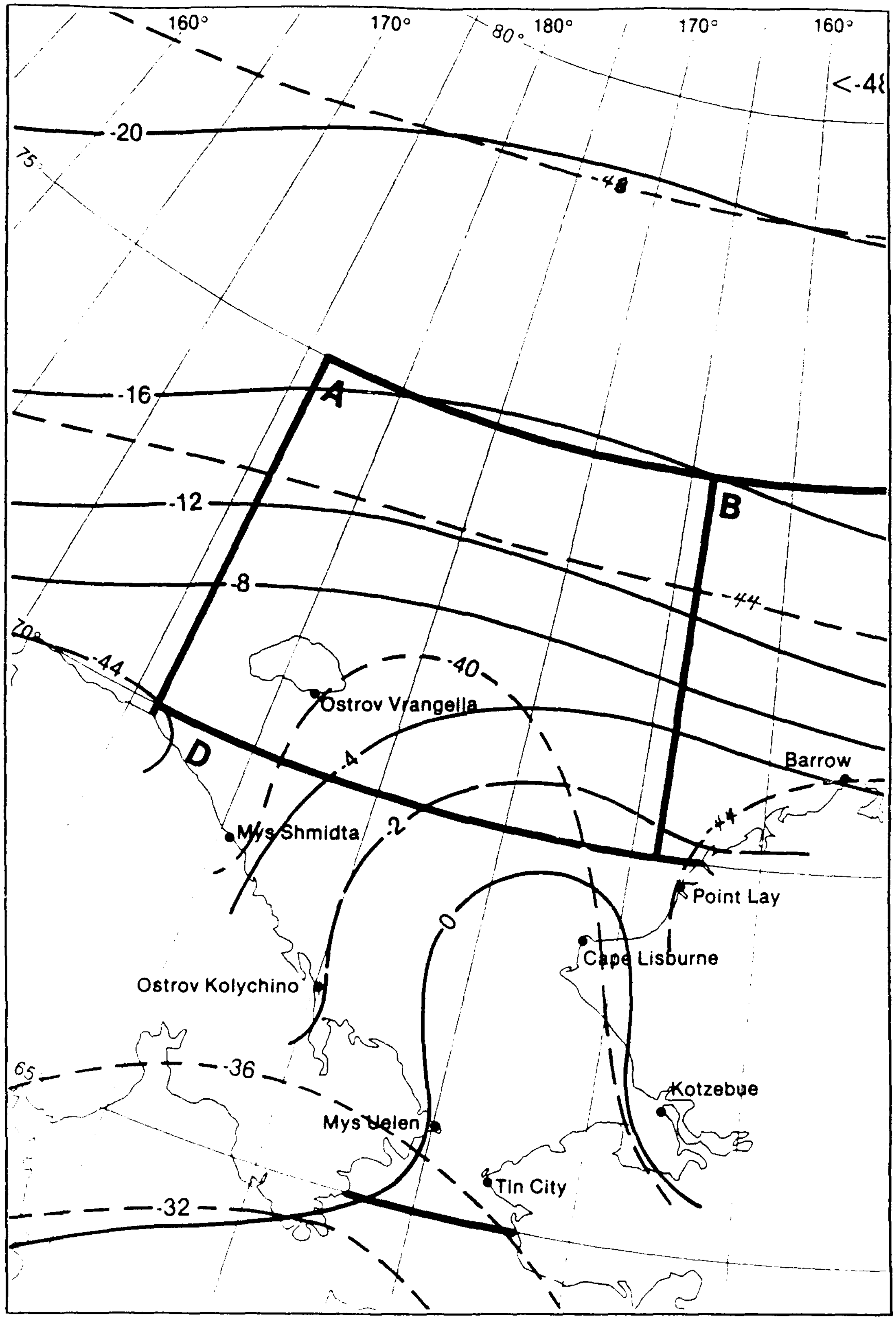
January

After Brower et al. 1988

Legend
99% Air Temperature °C (Max.)
1% Air Temperature °C (Min.)

Figure 20a

Air Temperature Extremes



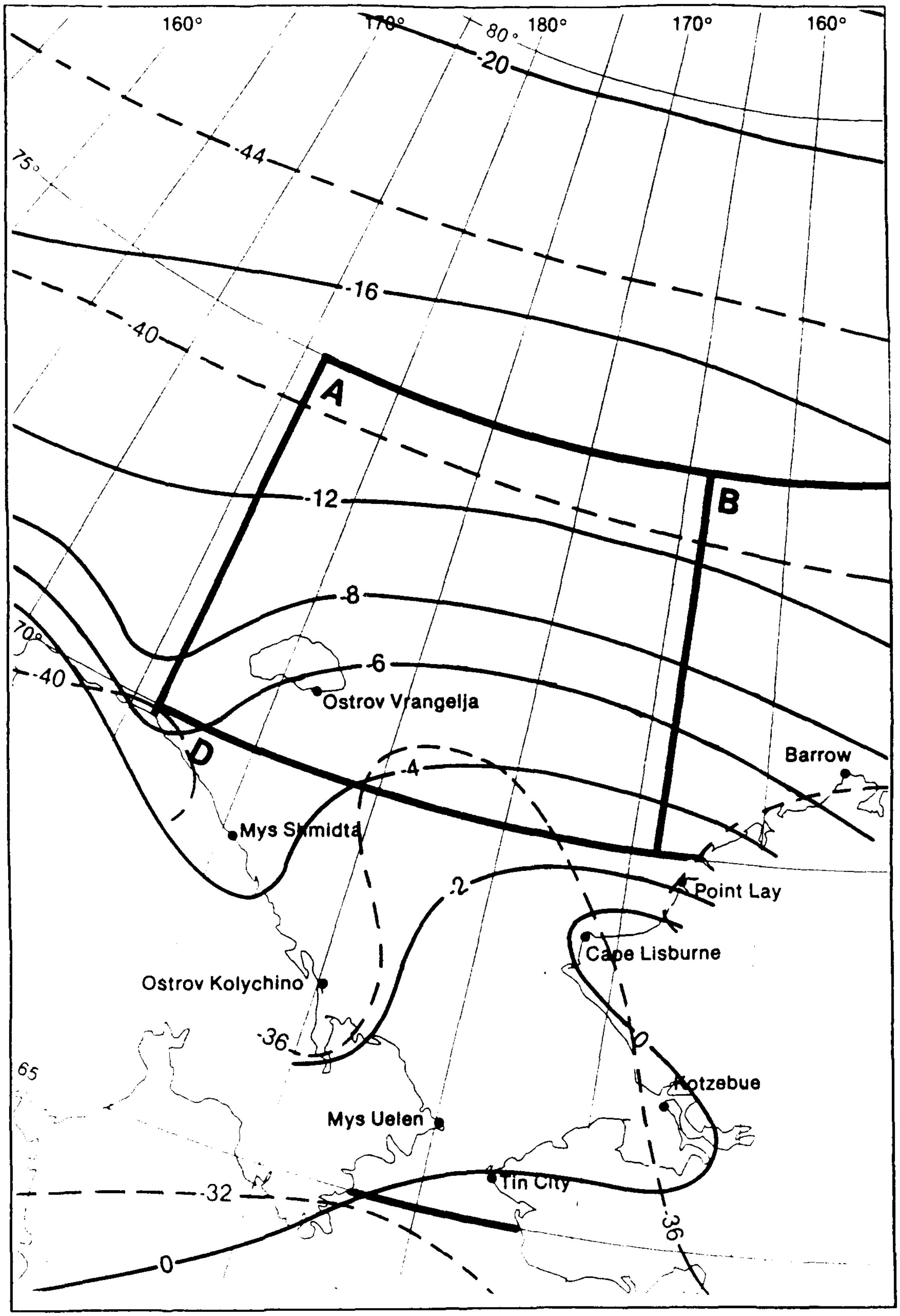
February

After Brower et al. 1988

Legend	
———	99% Air Temperature °C (Max.)
- - - -	1% Air Temperature °C (Min.)

Figure 20b

Air Temperature Extremes



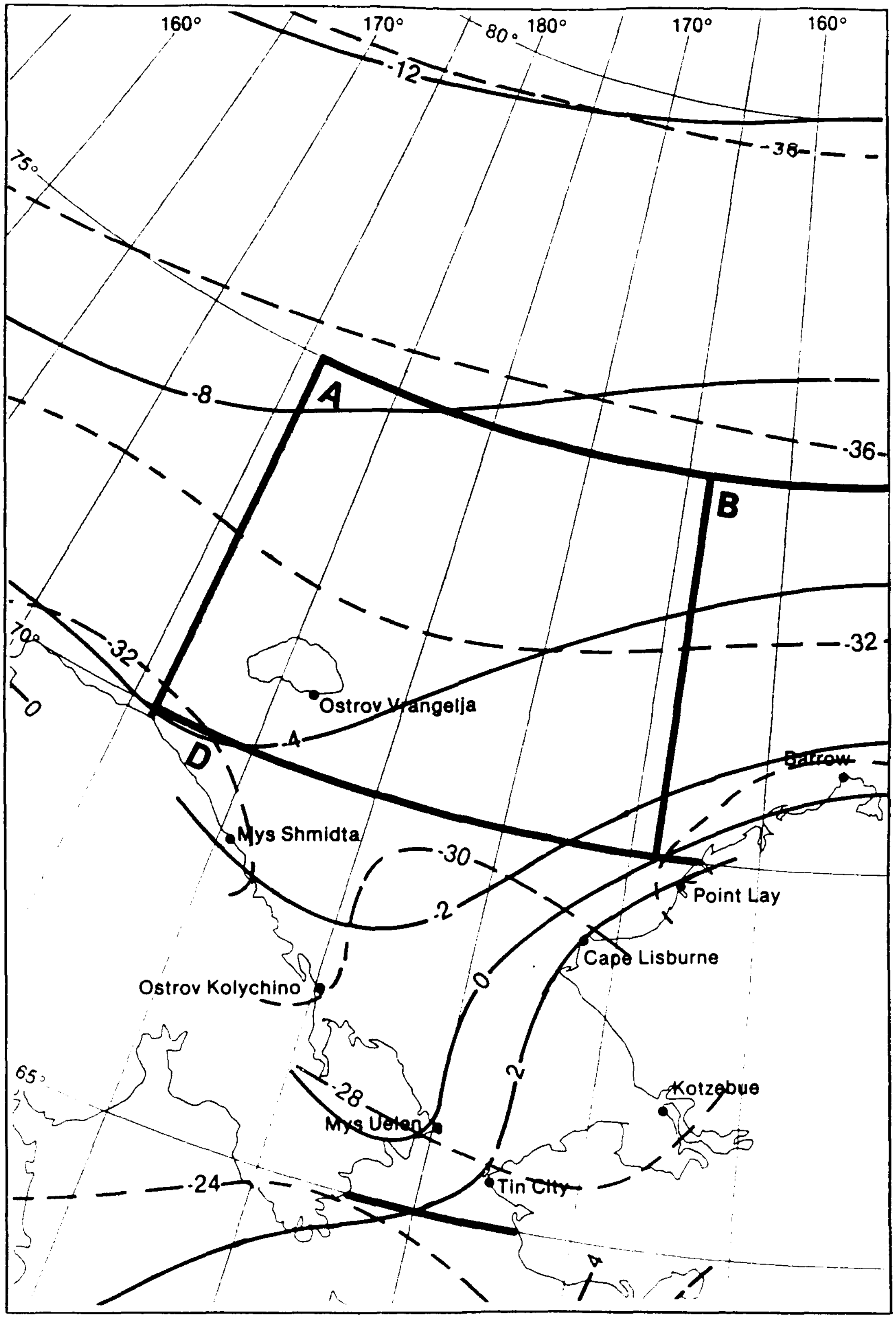
March

After Brower et al. 1988

Legend
99% Air Temperature °C (Max.)
1% Air Temperature °C (Min.)

Figure 20c

Air Temperature Extremes



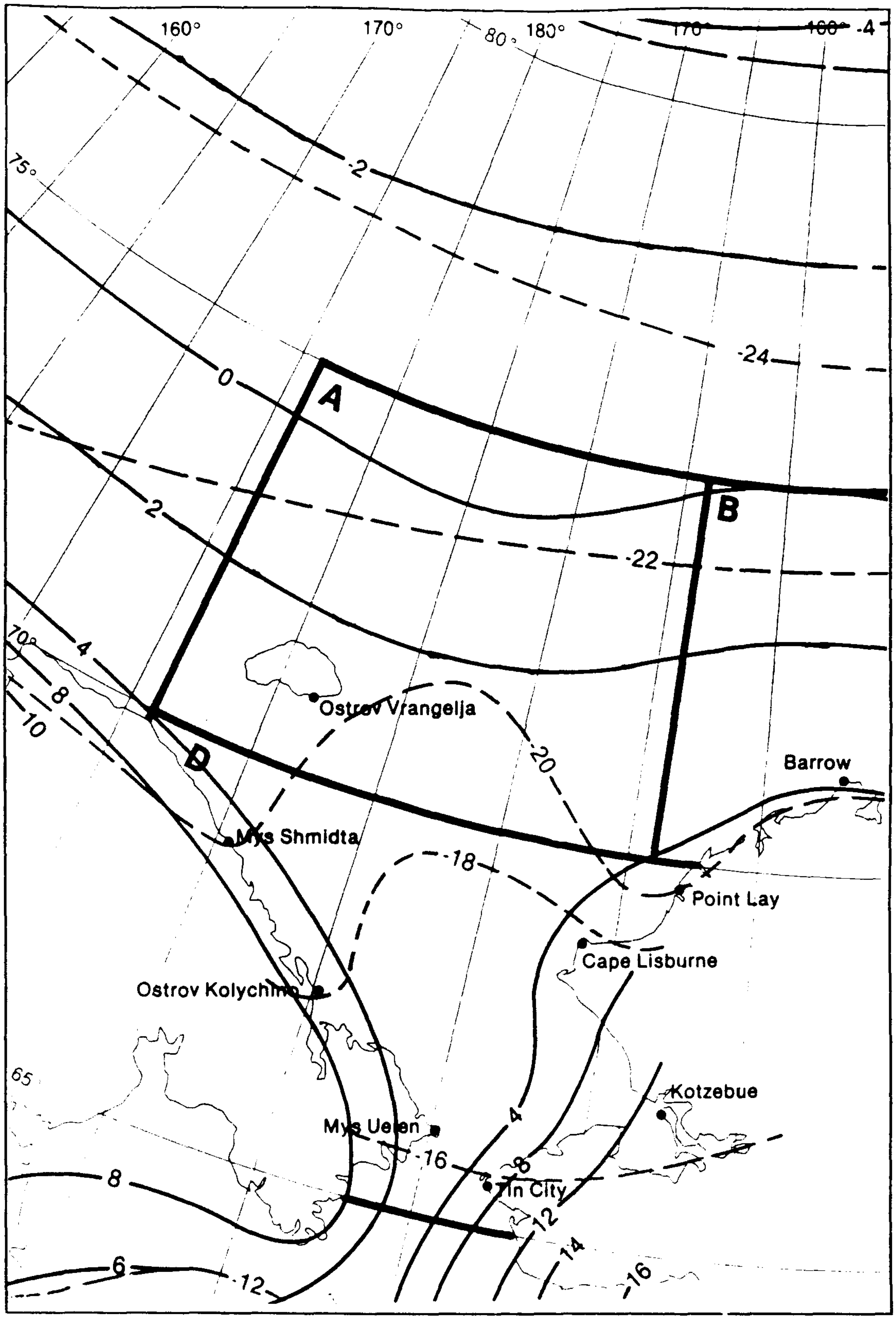
April

After Brower et al. 1988

Legend
99% Air Temperature °C (Max.)
1% Air Temperature °C (Min.)

Figure 20d

Air Temperature Extremes



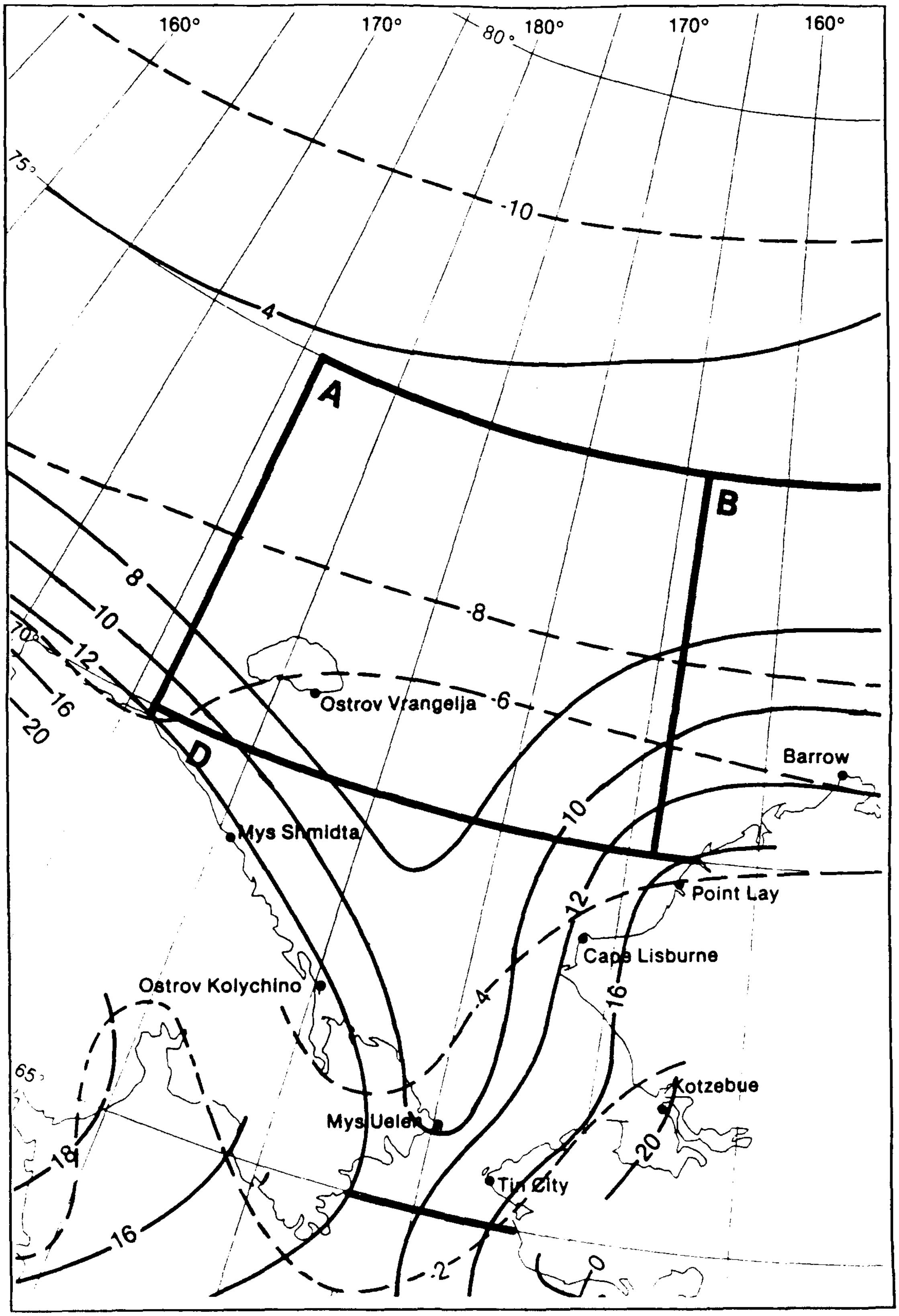
After Brower et al. 1988

Legend

------ 99% Air Temperature °C (Max.)
- - - - - 1% Air Temperature °C (Min.)

Figure 20e

Air Temperature Extremes



June

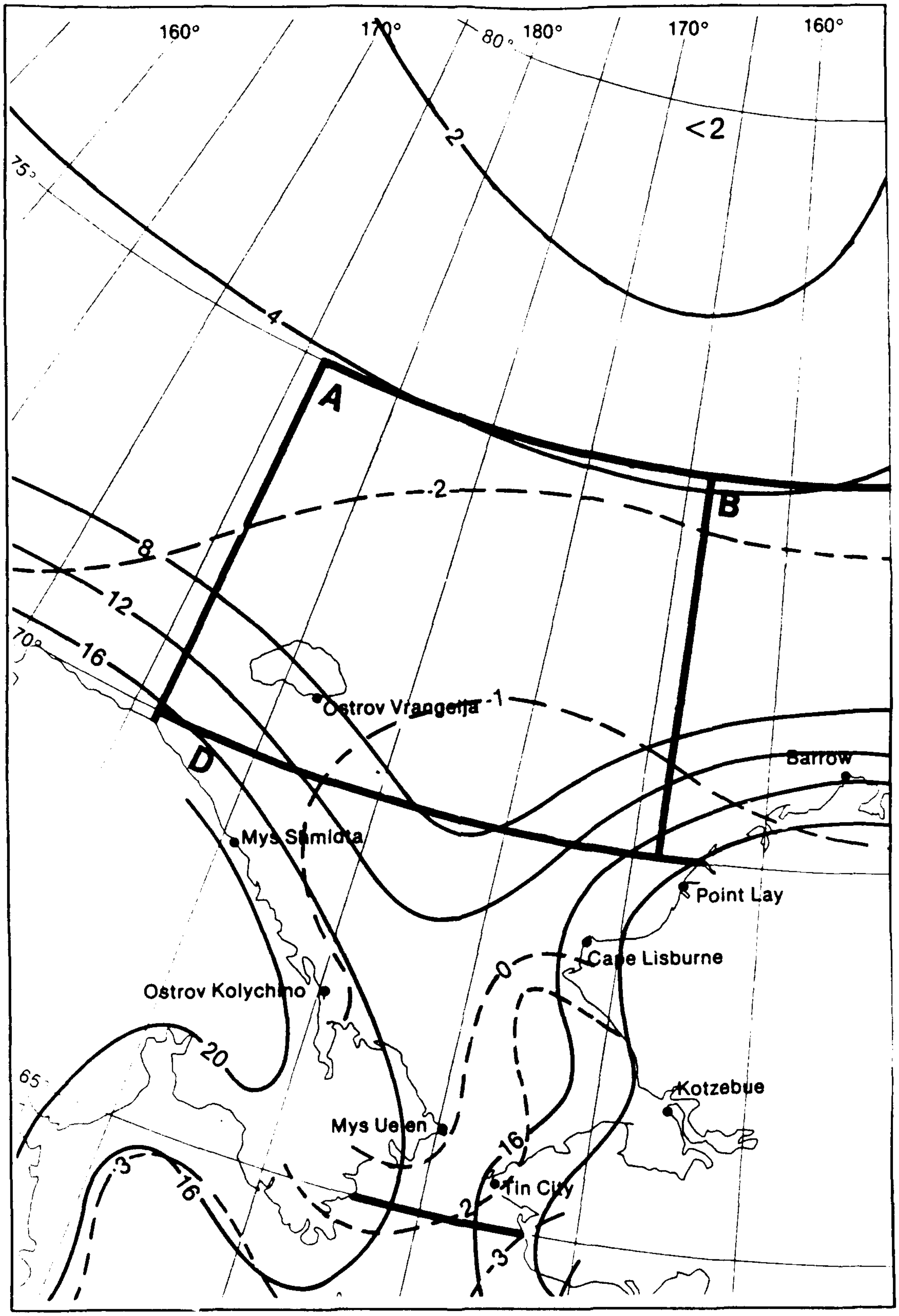
After Brower et al. 1988

Legend

99% Air Temperature °C (Max.)
1% Air Temperature °C (Min.)

Figure 20f

Air Temperature Extremes



July

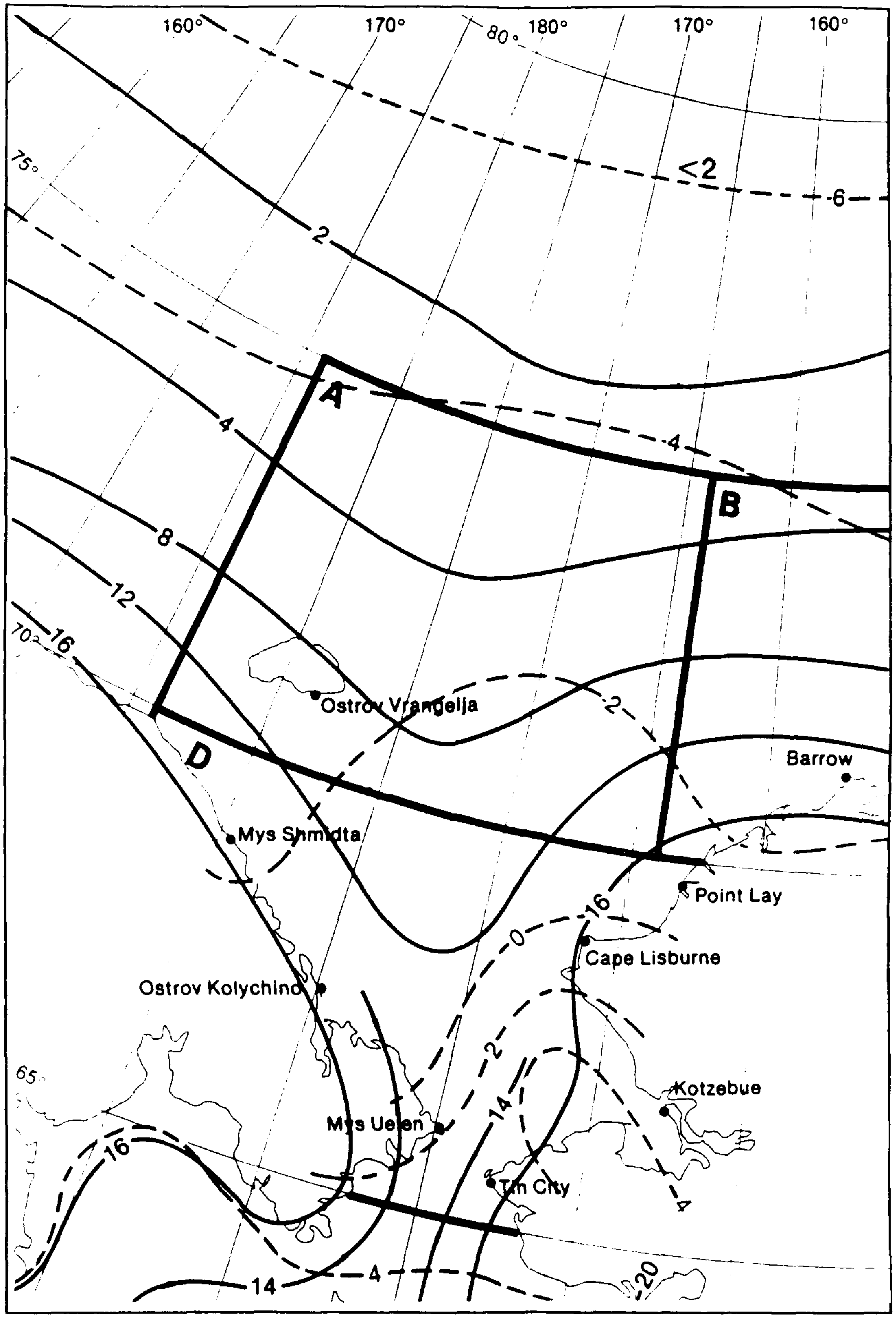
After Brower et al. 1988

Legend

99% Air Temperature °C (Max.)
1% Air Temperature °C (Min.)

Figure 20g

Air Temperature Extremes



August

After Brower et al. 1988

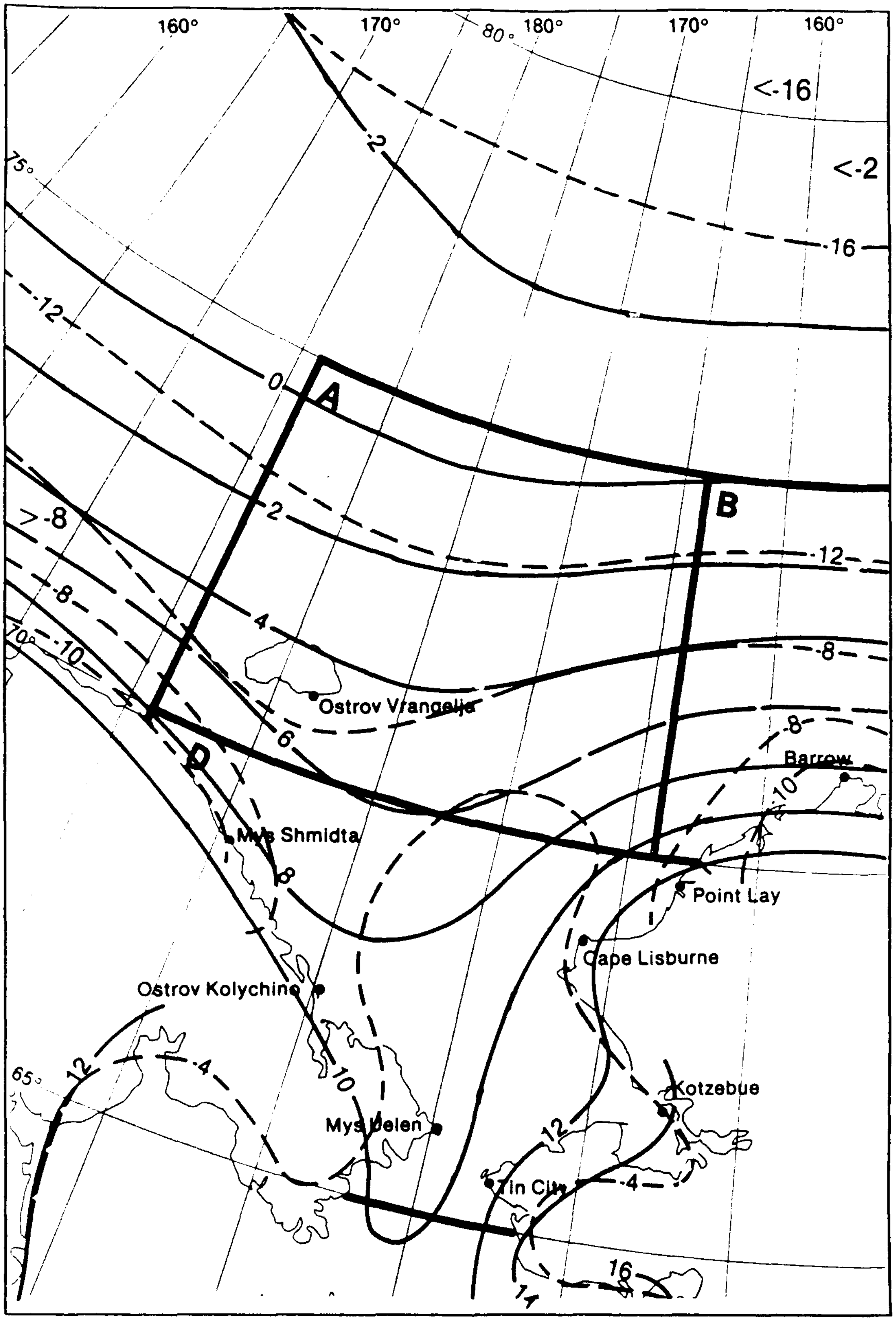
Legend

——— 99% Air Temperature °C (Max.)

- - - - 1% Air Temperature °C (Min.)

Figure 20h

Air Temperature Extremes



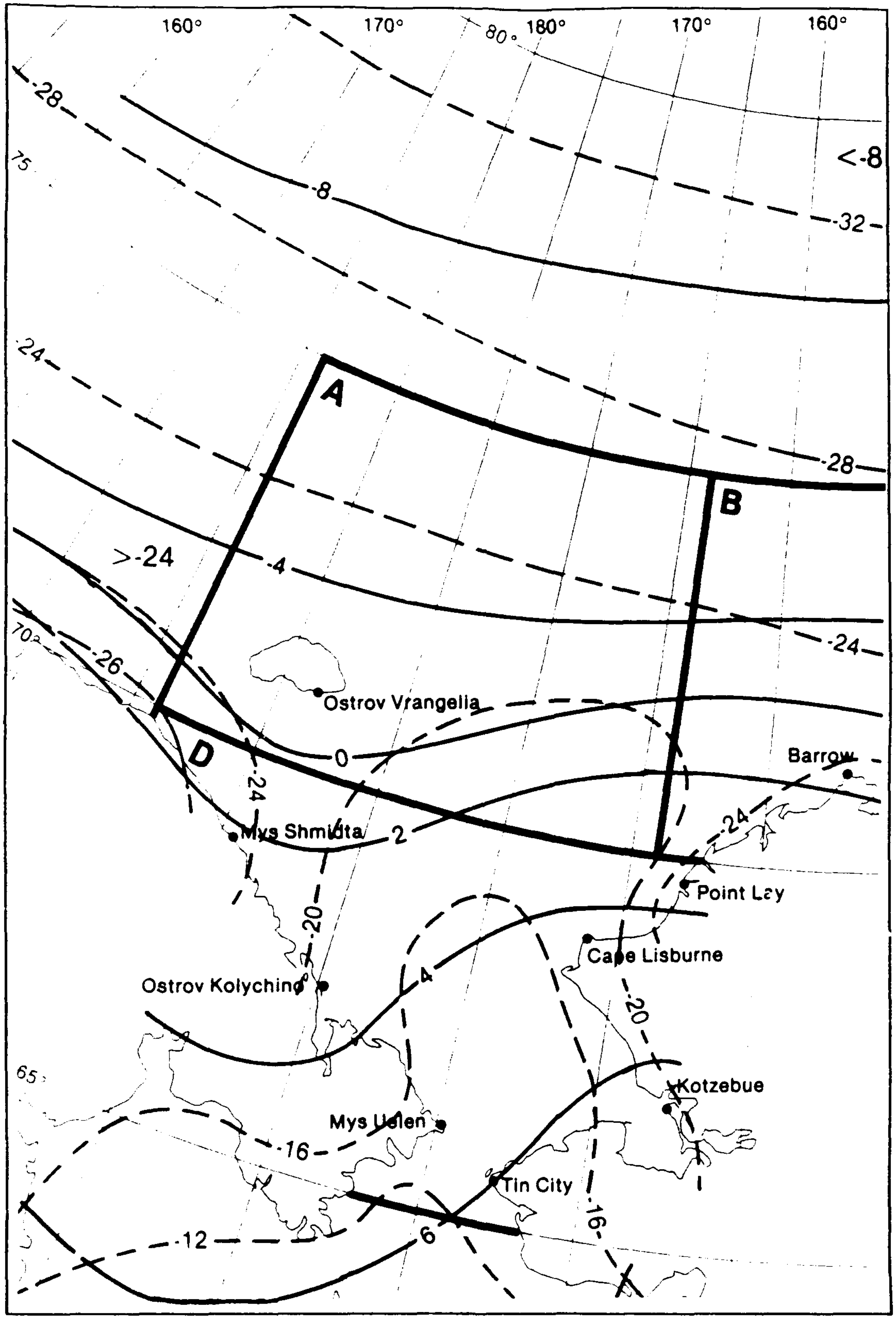
September

After Brower et al. 1988

Legend
99% Air Temperature °C (Max.)
1% Air Temperature °C (Min.)

Figure 20i

Air Temperature Extremes



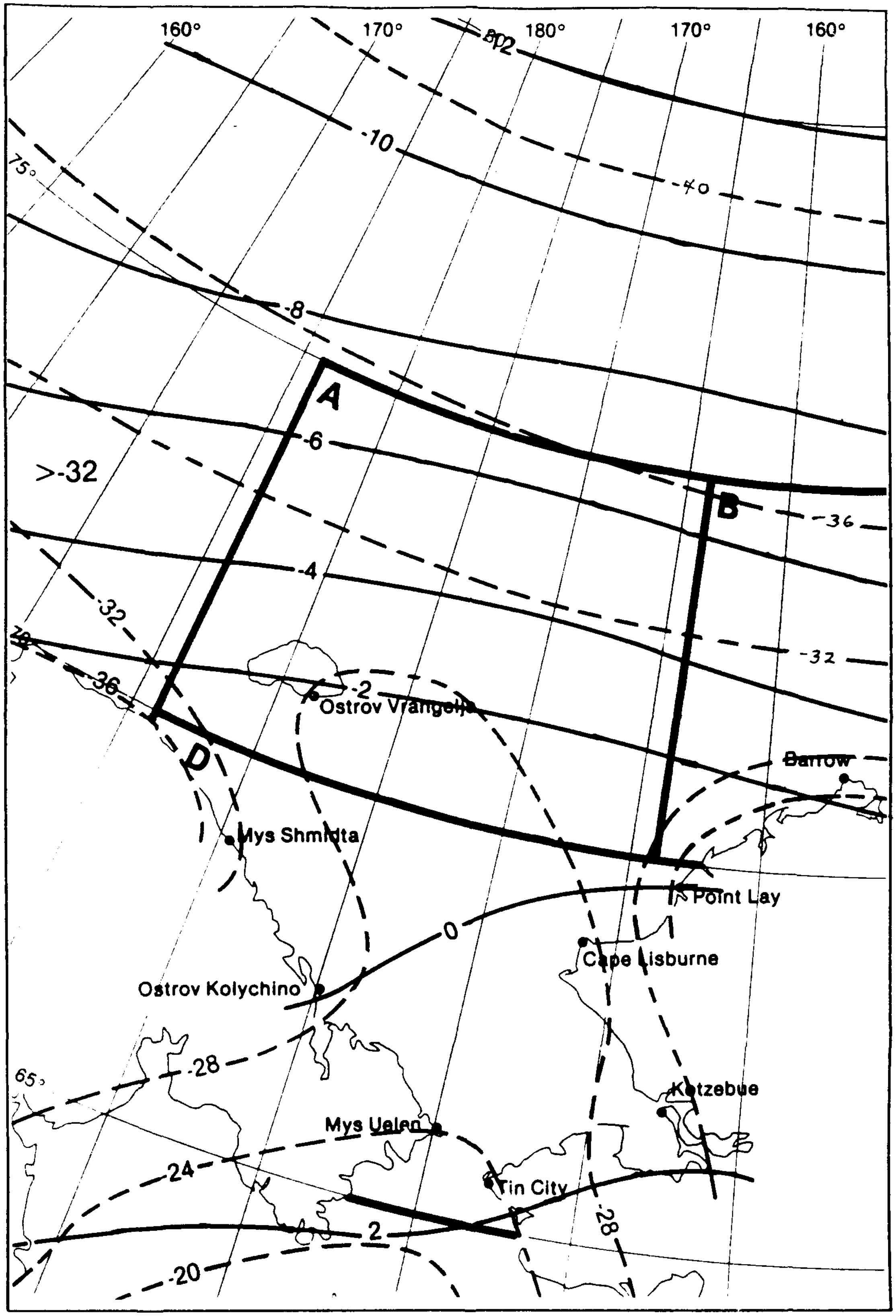
October

After Brower et al. 1988

Legend
99% Air Temperature °C (Max.)
1% Air Temperature °C (Min.)

Figure 20j

Air Temperature Extremes



November

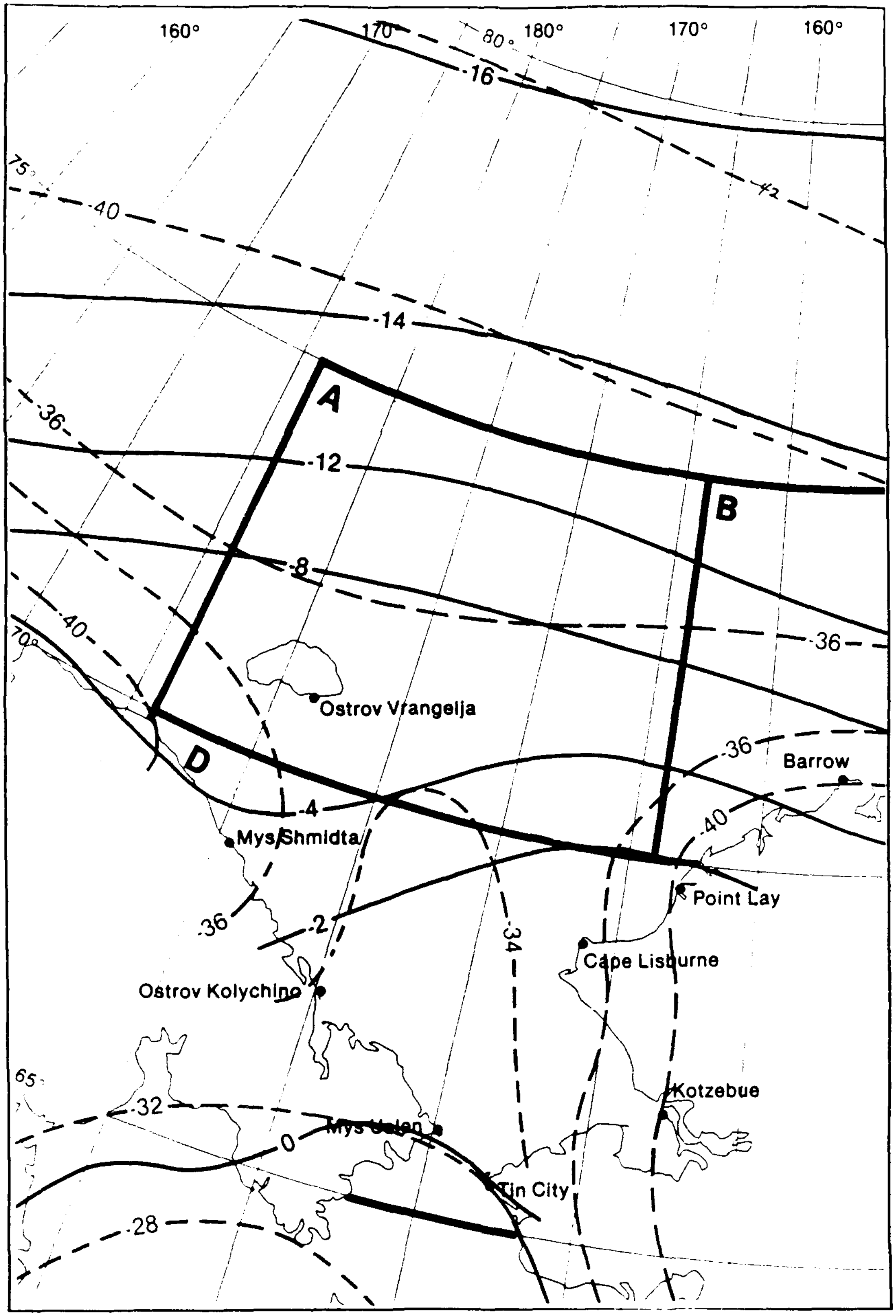
After Brower et al. 1988

Legend

------ 99% Air Temperature °C (Max.)
...... 1% Air Temperature °C (Min.)

Figure 20k

Air Temperature Extremes



December

After Brower et al. 1988

Legend
99% Air Temperature °C (Max.)
1% Air Temperature °C (Min.)

Figure 20l

Graphs: Air temperature/wind speed

1694 Wind Speed (knots)

TEMP (°C)	0–3	4–10	11–21	22–33	≥34
8,9	+	+	+	+	+
6,7	+	1	2	2	1
4,5	1	7	13	9	1
2,3	2	5	11	6	1
0,1	1	3	5	4	+
-2,-1	1	2	4	3	1
-4,-3	+	1	4	3	+
-6,-5	+	1	1	1	1
-8,-7	0	+	+	+	+
-10,-9	0	+	+	+	+
-12,-11	0	0	0	0	0

Percent frequency of simultaneous occurrence of specified temperature (°C) and wind speed (knots).

Number of observations.

(2% of all observations reported temperature 6-7°C simultaneously with wind speed of 22-33 knots.)

+ Indicates <.5% but >0.

Figure 21

Air Temperature/Wind Speed

Ostrov Vrangelje

4164 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-14	2	5	5	1	+
-16,-15	1	1	2	1	+
-18,-17	1	2	2	2	1
-20,-19	1	2	2	1	1
-22,-21	2	3	4	2	1
-24,-23	2	3	3	2	1
-26,-25	3	3	3	2	+
-28,-27	5	3	3	1	+
-30,-29	4	2	1	+	+
-32,-31	3	2	1	+	+
≤-33	7	2	+	+	0

Mys Shmidta

4703 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-16	3	6	5	2	+
-18,-17	2	2	2	1	+
-20,-19	1	2	2	+	+
-22,-21	1	2	4	1	+
-24,-23	1	3	4	1	+
-26,-25	2	3	4	1	+
-28,-27	3	4	5	2	1
-30,-29	1	2	2	1	+
-32,-31	2	2	3	1	+
-34,-33	2	2	2	+	+
≤-35	6	3	1	+	0

Ostrov Kolychino

2885 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-12	1	5	7	4	+
-14,-13	+	1	2	+	0
-16,-15	+	2	2	+	0
-18,-17	1	3	2	1	+
-20,-19	+	3	3	1	0
-22,-21	1	4	4	+	+
-24,-23	1	3	3	1	+
-26,-25	1	4	4	1	+
-28,-27	1	4	4	1	+
-30,-29	1	3	3	1	+
≤-31	5	9	4	+	+

Mys Uelen

4675 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-8	1	5	6	5	4
-10,-9	+	1	1	+	+
-12,-11	1	2	2	1	+
-14,-13	1	2	2	1	+
-16,-15	1	3	2	+	+
-18,-17	1	3	3	1	+
-20,-19	1	3	2	+	+
-22,-21	1	3	3	+	+
-24,-23	1	3	3	1	+
-26,-25	2	2	2	1	+
≤-27	6	7	8	2	+

Tin City

19113 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-8	3	6	10	4	+
-10,-9	1	2	3	1	+
-12,-11	1	1	2	1	+
-14,-13	1	1	3	2	+
-16,-15	+	1	2	2	+
-18,-17	+	1	2	2	+
-20,-19	+	1	3	3	+
-22,-21	1	1	3	3	+
-24,-23	1	1	4	4	+
-26,-25	+	1	3	2	1
≤-27	+	1	7	6	1

Kotzebue

22043 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-10	+	4	10	7	1
-12,-11	+	2	2	1	+
-14,-13	+	2	3	2	+
-16,-15	+	2	2	1	+
-18,-17	1	3	2	1	+
-20,-19	1	3	2	1	+
-22,-21	1	3	2	1	+
-24,-23	1	3	2	1	+
-26,-25	1	2	1	+	+
-28,-27	1	3	2	+	+
≤-29	6	11	4	1	+

Cape Lisburne

18369 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-8	2	4	6	6	1
-10,-9	1	2	1	1	+
-12,-11	1	2	1	+	+
-14,-13	1	2	1	+	+
-16,-15	1	2	1	+	+
-18,-17	1	3	2	+	+
-20,-19	1	4	3	1	+
-22,-21	1	4	2	+	+
-24,-23	1	4	3	1	+
-26,-25	1	3	2	+	+
≤-27	5	11	7	1	+

Point Lay

3299 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-16	3	10	7	2	+
-18,-17	1	2	1	1	+
-20,-19	1	2	2	1	+
-22,-21	1	2	2	1	+
-24,-23	1	2	2	1	+
-26,-25	1	2	2	1	+
-28,-27	1	3	3	1	+
-30,-29	2	3	3	1	+
-32,-31	1	2	2	1	+
-34,-33	1	3	2	1	+
≤-35	4	8	5	2	+

Barrow

18798 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-16	+	5	6	2	+
-18,-17	+	2	2	1	+
-20,-19	+	2	3	1	0
-22,-21	+	3	3	1	+
-24,-23	+	4	5	+	0
-26,-25	+	4	3	+	0
-28,-27	1	5	4	+	+
-30,-29	1	6	3	+	0
-32,-31	1	5	2	+	0
-34,-33	1	6	1	+	0
≤-35	3	12	1	+	0

Marine Area A

339 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-20	+	4	11	2	0
-22,-21	0	2	3	1	0
-24,-23	0	1	2	+	0
-26,-25	0	1	2	+	0
-28,-27	1	2	1	+	0
-30,-29	2	6	2	+	0
-32,-31	3	4	2	0	0
-34,-33	3	5	3	0	0
-36,-35	1	4	2	0	0
-38,-37	2	4	2	1	0
≤-39	10	7	3	+	0

Marine Area B

456 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-20	8	6	1	1	0
-22,-21	2	8	+	0	0
-24,-23	2	8	0	0	0
-26,-25	2	3	0	0	0
-28,-27	3	3	0	0	0
-30,-29	6	2	0	0	0
-32,-31	6	3	0	0	0
-34,-33	6	0	0	0	0
-36,-35	10	2	+	0	0
-38,-37	6	0	0	0	0
≤-39	13	+	0	+	0

Marine Area D

10 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥10	0	0	0	0	0
8,9	0	0	0	0	0
6,7	0	0	0	0	0
4,5	0	0	10	0	0
2,3	0	0	0	0	0
0,1	0	10	20	0	0
-2,-1	20	10	30	0	0
-4,-3	0	0	0	0	0
-6,-5	0	0	0	0	0
-8,-7	0	0	0	0	0
≤-9	0	0	0	0	0

January

After Brower et al. 1988

Figure 21a

Air Temperature/Wind Speed

Ostrov Vrangelja

3890 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-16	1	3	2	+	+
-18,-17	1	1	1	1	+
-20,-19	1	1	2	1	+
-22,-21	2	3	3	2	+
-24,-23	3	3	3	2	+
-26,-25	3	4	3	2	+
-28,-27	6	3	2	1	1
-30,-29	4	2	1	1	+
-32,-31	7	2	1	+	+
-34,-33	6	1	+	+	+
≤-35	9	1	+	+	+

Mys Shmidta

43[illegible] Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-18	1	4	3	1	+
-20,-19	+	1	1	+	+
-22,-21	1	2	2	1	+
-24,-23	1	3	2	1	+
-26,-25	2	3	4	2	+
-28,-27	2	5	6	3	+
-30,-29	1	2	3	1	+
-32,-31	3	3	4	2	+
-34,-33	2	3	3	1	+
-36,-35	4	3	2	1	+
≤-37	5	3	1	+	0

Ostrov Kolychino

2768 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-16	1	4	5	2	+
-18,-17	1	2	2	1	+
-20,-19	1	1	2	+	+
-22,-21	1	2	3	+	0
-24,-23	1	2	4	1	0
-26,-25	1	2	5	1	+
-28,-27	1	5	5	2	+
-30,-29	1	3	3	1	+
-32,-31	2	6	4	+	0
-34,-33	2	6	2	+	0
≤-35	2	7	2	+	0

Mys Uelen

4357 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-14	2	4	5	3	2
-16,-15	1	2	1	+	+
-18,-17	1	3	2	+	+
-20,-19	1	2	1	+	0
-22,-21	1	3	3	+	0
-24,-23	1	3	3	1	0
-26,-25	1	2	4	+	+
-28,-27	3	4	6	1	+
-30,-29	2	3	3	+	+
-32,-31	3	4	3	+	+
≤-33	5	5	3	1	0

Tin City

17416 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-12	3	5	8	3	+
-14,-13	1	1	2	1	+
-16,-15	1	1	2	2	+
-18,-17	1	1	3	3	+
-20,-19	+	1	3	3	+
-22,-21	+	+	2	3	+
-24,-23	+	1	4	5	1
-26,-25	+	1	3	5	1
-28,-27	+	+	3	4	1
-30,-29	+	1	4	4	1
≤-31	+	1	6	6	1

Kotzebue

19709 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-12	1	5	10	5	1
-14,-13	+	2	2	1	+
-16,-15	+	2	2	1	+
-18,-17	+	2	2	1	+
-20,-19	1	3	2	1	+
-22,-21	1	3	2	+	+
-24,-23	1	4	3	+	+
-26,-25	1	3	2	+	+
-28,-27	2	4	2	+	+
-30,-29	2	4	1	+	+
≤-31	6	9	2	+	+

Cape Lisburne

16993 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-14	3	5	5	4	1
-16,-15	1	2	1	+	+
-18,-17	1	2	1	+	+
-20,-19	1	3	2	+	0
-22,-21	1	4	2	+	+
-24,-23	2	5	4	+	+
-26,-25	2	4	3	+	+
-28,-27	2	5	3	+	+
-30,-29	2	5	3	+	+
-32,-31	2	3	2	+	+
≤-33	4	6	3	+	+

Point Lay

2997 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-20	3	8	7	2	+
-22,-21	1	2	1	+	+
-24,-23	1	2	1	1	+
-26,-25	1	2	2	1	0
-28,-27	1	3	2	1	+
-30,-29	1	4	4	1	+
-32,-31	1	3	3	1	+
-34,-33	1	3	3	1	+
-36,-35	1	3	3	1	+
-38,-37	1	4	2	1	0
≤-39	3	8	4	+	0

Barrow

17135 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-20	+	6	6	1	+
-22,-21	+	2	3	+	+
-24,-23	+	2	4	+	+
-26,-25	+	2	3	+	0
-28,-27	+	5	4	+	0
-30,-29	1	8	4	+	0
-32,-31	1	6	2	+	0
-34,-33	1	8	2	+	0
-36,-35	1	6	1	+	0
-38,-37	1	6	1	0	0
≤-39	1	7	1	0	0

Marine Area A

275 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-20	4	6	2	2	0
-22,-21	+	2	+	+	0
-24,-23	1	1	2	1	0
-26,-25	0	2	3	+	0
-28,-27	2	3	3	0	0
-30,-29	1	3	1	0	0
-32,-31	1	3	4	0	0
-34,-33	+	8	5	0	0
-36,-35	3	8	5	0	0
-38,-37	3	11	1	0	0
≤-39	1	7	+	0	0

Marine Area B

259 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-24	3	5	7	3	0
-26,-25	2	2	+	0	0
-28,-27	2	1	+	0	0
-30,-29	2	4	1	0	0
-32,-31	5	2	+	0	0
-34,-33	8	+	0	0	0
-36,-35	8	0	0	0	0
-38,-37	10	0	0	0	0
-40,-39	19	0	0	0	0
-42,-41	9	0	0	0	0
≤-43	5	0	0	0	0

Marine Area D

40 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-6	0	0	5	0	0
-8,-7	0	2	13	0	0
-10,-9	0	5	0	2	0
-12,-11	0	2	5	5	0
-14,-13	0	7	2	2	0
-16,-15	0	2	2	0	0
-18,-17	2	0	7	0	0
-20,-19	0	5	10	5	0
-22,-21	0	0	5	0	0
-24,-23	0	0	2	0	0
≤-25	0	0	5	0	0

After Brower et al. 1988

February

Figure 21b

Air Temperature/Wind Speed

Ostrov Vrangelja

4389 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-14	1	3	3	1	+
-16,-15	1	2	2	1	+
-18,-17	1	2	3	1	+
-20,-19	1	1	3	2	+
-22,-21	3	3	4	2	1
-24,-23	4	3	3	2	1
-26,-25	4	3	2	1	+
-28,-27	6	3	2	1	+
-30,-29	4	2	1	+	+
-32,-31	5	2	1	+	0
≤-33	7	2	+	+	+

Mys Shmidta

4882 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-16	2	3	3	1	+
-18,-17	1	2	1	+	+
-20,-19	1	1	1	+	+
-22,-21	2	3	3	1	+
-24,-23	1	4	4	2	+
-26,-25	2	4	6	2	+
-28,-27	3	4	6	2	1
-30,-29	1	3	3	2	+
-32,-31	2	3	3	1	+
-34,-33	3	2	2	+	+
≤-35	5	2	1	+	0

Ostrov Kolychino

2992 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-14	1	3	5	2	+
-16,-15	1	1	1	+	0
-18,-17	1	3	2	+	0
-20,-19	+	2	2	+	0
-22,-21	1	3	3	1	0
-24,-23	1	4	4	1	0
-26,-25	1	4	5	1	0
-28,-27	1	7	6	1	+
-30,-29	1	5	3	+	+
-32,-31	2	6	2	+	0
≤-33	2	7	2	+	0

Mys Uelen

4845 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-12	2	5	5	3	1
-14,-13	+	1	1	+	+
-16,-15	1	2	2	+	0
-18,-17	2	4	2	+	+
-20,-19	1	3	3	+	0
-22,-21	2	4	4	+	0
-24,-23	2	5	4	+	+
-26,-25	2	4	4	+	+
-28,-27	3	3	4	1	+
-30,-29	1	2	2	+	0
≤-31	5	4	2	+	0

Tin City

19490 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-10	3	6	7	3	+
-12,-11	+	1	2	1	+
-14,-13	1	1	3	2	+
-16,-15	+	1	2	3	+
-18,-17	1	1	3	3	+
-20,-19	+	1	4	5	+
-22,-21	+	1	3	4	+
-24,-23	+	1	4	6	1
-26,-25	+	1	3	3	1
-28,-27	+	1	3	3	1
≤-29	+	1	4	4	1

Kotzebue

21958 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-8	+	4	7	3	+
-10,-9	+	3	3	1	+
-12,-11	+	2	2	1	+
-14,-13	1	4	2	1	+
-16,-15	1	3	2	1	+
-18,-17	1	4	2	1	+
-20,-19	2	5	2	1	+
-22,-21	1	3	2	+	+
-24,-23	1	5	2	+	+
-26,-25	1	3	1	+	+
≤-27	5	11	4	1	+

Cape Lisburne

19166 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-12	3	4	4	3	1
-14,-13	1	2	1	+	+
-16,-15	1	2	1	+	+
-18,-17	1	3	1	+	+
-20,-19	2	4	3	+	+
-22,-21	1	5	3	+	+
-24,-23	1	6	5	1	+
-26,-25	1	4	3	+	+
-28,-27	2	4	3	+	+
-30,-29	2	4	2	+	+
≤-31	4	4	2	+	+

Point Lay

3327 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-18	2	8	4	1	+
-20,-19	1	2	1	1	0
-22,-21	1	2	2	1	+
-24,-23	1	3	3	2	+
-26,-25	1	2	2	2	+
-28,-27	1	4	3	2	+
-30,-29	1	5	4	2	+
-32,-31	1	4	3	1	+
-34,-33	1	4	3	1	0
-36,-35	1	3	2	+	0
≤-37	3	6	3	+	+

Barrow

18810 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-18	+	4	4	1	+
-20,-19	+	3	3	+	+
-22,-21	+	3	3	+	+
-24,-23	1	6	6	1	+
-26,-25	+	5	5	+	0
-28,-27	1	9	6	+	0
-30,-29	1	9	4	+	0
-32,-31	1	6	2	+	0
-34,-33	+	6	1	0	0
-36,-35	+	3	1	0	0
≤-37	+	4	1	0	0

Marine Area A

297 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-18	+	6	9	2	0
-20,-19	+	2	2	0	0
-22,-21	1	3	2	+	0
-24,-23	+	3	3	+	0
-26,-25	+	3	3	1	0
-28,-27	+	5	3	+	0
-30,-29	+	9	2	0	0
-32,-31	2	5	3	0	0
-34,-33	1	6	1	0	0
-36,-35	+	7	3	0	0
≤-37	2	5	1	0	0

Marine Area B

56 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-14	0	0	5	2	0
-16,-15	0	5	2	0	0
-18,-17	2	5	13	0	0
-20,-19	0	4	7	0	0
-22,-21	0	2	2	0	0
-24,-23	0	4	2	0	0
-26,-25	0	7	2	0	0
-28,-27	0	4	2	0	0
-30,-29	2	0	5	0	0
-32,-31	0	13	5	0	0
≤-33	4	4	0	0	0

Marine Area D

101 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-4	0	6	1	1	0
-6,-5	0	6	5	1	0
-8,-7	0	2	0	0	0
-10,-9	1	4	3	1	0
-12,-11	0	2	5	2	0
-14,-13	0	2	9	1	0
-16,-15	0	3	7	8	1
-18,-17	0	2	6	2	1
-20,-19	0	1	1	0	1
-22,-21	0	2	0	0	0
≤-23	0	2	6	5	1

After Brower et al. 1988

March

Figure 21c

Air Temperature/Wind Speed

Ostrov Vran[illegible]ja

4427 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-10	2	3	3	+	+
-12,-11	1	2	2	1	+
-14,-13	2	2	2	1	+
-16,-15	3	3	3	1	+
-18,-17	4	5	4	3	+
-20,-19	3	3	2	2	+
-22,-21	5	4	3	2	+
-24,-23	5	3	2	1	+
-26,-25	5	2	1	+	+
-28,-27	4	1	+	+	0
≤-29	3	+	0	0	+

[illegible] Shmidta

4665 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-10	2	5	3	1	0
-12,-11	1	2	1	+	+
-14,-13	1	2	2	+	+
-16,-15	2	3	3	+	+
-18,-17	2	5	4	1	+
-20,-19	2	3	3	1	+
-22,-21	3	5	5	1	+
-24,-23	3	5	4	1	+
-26,-25	3	4	3	+	+
-28,-27	3	3	2	+	+
≤-29	4	2	+	+	0

Ostrov Kolychino

2719 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-8	1	5	5	1	+
-10,-9	+	1	2	+	0
-12,-11	1	2	2	+	0
-14,-13	1	3	2	+	0
-16,-15	1	4	3	1	0
-18,-17	1	5	4	1	+
-20,-19	2	4	3	1	+
-22,-21	2	6	5	1	0
-24,-23	2	7	3	+	+
-26,-25	2	5	1	+	+
≤-27	2	7	1	+	0

Mys Uelen

4644 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-6	2	4	5	2	1
-8,-7	2	2	2	+	+
-10,-9	1	1	1	+	0
-12,-11	2	3	2	+	0
-14,-13	2	3	2	+	0
-16,-15	1	3	4	1	0
-18,-17	3	6	6	1	0
-20,-19	2	4	3	+	+
-22,-21	3	4	3	+	0
-24,-23	3	3	2	+	0
≤-25	4	3	2	+	0

Tin City

19252 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-4	2	5	9	3	+
-6,-5	+	1	3	1	+
-8,-7	+	1	3	1	+
-10,-9	+	2	3	2	+
-12,-11	+	1	3	2	+
-14,-13	1	2	4	3	+
-16,-15	1	1	5	3	+
-18,-17	1	2	5	4	+
-20,-19	+	1	5	4	+
-22,-21	+	+	3	3	+
≤-23	+	+	4	3	+

Kotzebue

21265 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-2	1	5	6	2	+
-4,-3	1	3	3	1	+
-6,-5	1	3	2	+	+
-8,-7	1	5	3	1	+
-10,-9	1	5	3	1	+
-12,-11	1	3	2	1	+
-14,-13	1	5	3	1	+
-16,-15	1	3	2	+	0
-18,-17	1	4	2	+	+
-20,-19	1	4	2	+	+
≤-21	3	9	2	+	+

Cape Lisburne

19118 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-6	2	5	6	3	+
-8,-7	1	2	1	1	+
-10,-9	1	3	1	+	+
-12,-11	2	2	1	+	+
-14,-13	3	5	2	+	+
-16,-15	2	5	2	+	+
-18,-17	3	5	3	+	[illegible]
-20,-19	2	6	3	+	0
-22,-21	2	5	3	+	0
-24,-23	2	4	2	+	+
≤-25	2	3	2	+	+

Point Lay

3158 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-10	2	7	5	2	+
-12,-11	1	2	1	+	+
-14,-13	1	3	2	+	+
-16,-15	1	4	2	1	+
-18,-17	1	4	3	1	+
-20,-19	2	4	3	1	+
-22,-21	1	4	3	1	+
-24,-23	1	4	4	2	+
-26,-25	1	3	2	1	+
-28,-27	1	3	2	1	+
≤-29	2	6	3	1	0

Barrow

18230 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-10	1	6	6	+	0
-12,-11	+	2	2	+	0
-14,-13	+	4	4	+	0
-16,-15	+	4		+	+
-18,-17	1	5		+	+
-20,-19	1	7		+	0
-22,-21	1	6		+	0
-24,-23	1	7	4	+	0
-26,-25	1	5	2	+	0
-28,-27	1	6	1	+	0
≤-29	+	6	1	+	0

Marine Area A

279 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-14	[illegible]	2	5	1	0
-16,-15	+	4	2	0	0
-18,-17	1	3	3	0	0
-20,-19	+	2	+	0	0
-22,-21	0	1	1	0	0
-24,-23	3	6	3	0	0
-26,-25	0	9	1	0	0
-28,-27	1	9	2	0	0
-30,-29	1	13	1	0	0
-32,-31	+	8	1	0	0
≤-33	1	5	0	0	0

Marine Area B

192 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-6	0	5	9	1	0
-8,-7	1	1	3	0	0
-10,-9	0	1	3	0	1
-12,-11	0	1	6	1	0
-14,-13	0	0	5	4	0
-16,-15	0	1	5	4	0
-18,-17	0	0	4	4	0
-20,-19	1	4	7	4	1
-22,-21	1	8	6	3	2
-24,-23	0	4	3	1	3
≤-25	0	1	0	0	0

Marine Area D

179 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥0	1	4	6	2	0
-2,-1	1	3	9	0	1
-4,-3	1	3	4	1	0
-6,-5	1	1	4	0	0
-8,-7	0	1	4	0	0
-10,-9	0	2	3	0	0
-12,-11	1	9	4	0	0
-14,-13	3	6	6	0	0
-16,-15	0	7	4	0	0
-18,-17	1	2	2	0	0
≤-19	1	2	1	1	1

April

After Brower et al. 1988

Figure 21d

Air Temperature/Wind Speed

Ostrov Vrangelja

4241 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥2	1	1	+	+	0
0,1	1	2	+	+	+
-2,-1	2	6	2	+	+
-4,-3	4	6	3	1	+
-6,-5	3	7	4	1	+
-8,-7	3	8	5	2	1
-10,-9	3	4	3	1	+
-12,-11	2	4	3	1	+
-14,-13	2	2	2	+	0
-16,-15	1	1	1	+	+
≤-17	2	1	+	+	+

Mys Shmidta

4486 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥2	2	3	1	+	0
0,1	1	2	1	+	0
-2,-1	2	6	3	+	+
-4,-3	2	8	5	+	+
-6,-5	2	8	4	1	0
-8,-7	2	7	4	+	+
-10,-9	1	3	3	1	+
-12,-11	2	4	3	+	+
-14,-13	1	4	2	+	+
-16,-15	1	2	1	+	0
≤-17	2	2	1	+	0

Ostrov Kolychino

2906 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥4	+	1	+	0	0
2,3	1	1	2	+	0
0,1	+	3	3	+	0
-2,-1	1	7	4	1	+
-4,-3	2	9	5	1	+
-6,-5	2	9	5	+	+
-8,-7	1	7	4	1	+
-10,-9	1	4	2	+	0
-12,-11	1	5	2	+	0
-14,-13	+	5	3	+	0
≤-15	+	4	2	+	0

Mys Uelen

4512 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥4	+	+	+	0	0
2,3	1	1	1	+	+
0,1	3	4	3	1	+
-2,-1	3	9	7	3	1
-4,-3	3	9	6	1	+
-6,-5	2	7	4	+	0
-8,-7	2	5	3	+	0
-10,-9	1	3	3	+	0
-12,-11	1	2	2	+	0
-14,-13	1	1	2	+	0
≤-15	1	1	1	+	+

Tin City

20704 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥6	1	1	+	+	0
4,5	1	1	1	+	0
2,3	1	2	3	+	+
0,1	2	5	9	2	+
-2,-1	1	5	11	3	+
-4,-3	1	4	10	4	+
-6,-5	+	2	5	3	+
-8,-7	1	1	3	2	+
-10,-9	+	1	3	1	0
-12,-11	+	1	2	1	0
≤-13	+	1	2	2	+

Kotzebue

21217 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥8	+	2	2	+	0
6,7	+	3	1	+	0
4,5	1	4	2	+	0
2,3	2	10	6	+	0
0,1	3	13	7	1	+
-2,-1	1	7	4	+	0
-4,-3	1	6	3	+	0
-6,-5	1	3	1	+	+
-8,-7	1	2	1	+	0
-10,-9	1	2	1	+	0
≤-11	2	3	2	+	0

Cape Lisburne

20422 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥6	1	1	+	+	+
4,5	1	1	1	+	+
2,3	2	3	2	1	+
0,1	3	6	4	1	+
-2,-1	3	8	4	1	+
-4,-3	3	10	6	1	+
-6,-5	2	6	4	+	0
-8,-7	1	5	3	+	+
-10,-9	1	3	2	+	0
-12,-11	1	2	1	+	0
≤-13	2	4	2	+	0

Point Lay

3181 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥4	1	2	1	+	0
2,3	1	4	2	+	0
0,1	2	6	3	1	+
-2,-1	1	6	4	1	+
-4,-3	2	6	5	2	+
-6,-5	1	4	4	1	+
-8,-7	2	4	4	2	+
-10,-9	1	3	3	2	+
-12,-11	1	2	2	1	+
-14,-13	1	3	2	1	0
≤-15	1	3	2	1	0

Barrow

18097 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥2	+	1	+	+	0
0,1	+	3	1	+	0
-2,-1	+	4	3	+	0
-4,-3	1	8	6	+	0
-6,-5	1	8	7	+	0
-8,-7	1	9	8	+	0
-10,-9	1	7	6	+	0
-12,-11	+	5	3	+	0
-14,-13	+	5	3	+	0
-16,-15	+	2	1	+	0
≤-17	+	3	1	+	0

Marine Area A

182 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-2	0	3	2	1	0
-4,-3	1	4	2	0	0
-6,-5	0	4	4	0	0
-8,-7	2	5	9	0	0
-10,-9	1	6	8	0	0
-12,-11	0	5	7	2	0
-14,-13	1	5	5	1	0
-16,-15	1	3	3	0	0
-18,-17	0	4	3	0	0
-20,-19	0	6	1	0	0
≤-21	0	3	0	0	0

Marine Area B

34 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥0	0	0	0	0	0
-2,-1	0	0	3	0	0
-4,-3	0	6	0	0	0
-6,-5	0	9	3	6	0
-8,-7	6	6	3	0	0
-10,-9	3	0	6	6	3
-12,-11	0	0	9	0	0
-14,-13	3	9	12	0	0
-16,-15	0	3	6	0	0
-18,-17	0	0	0	0	0
≤-19	0	0	0	0	0

Marine Area D

167 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥8	0	0	0	0	0
6,7	0	0	0	0	0
4,5	0	1	0	0	0
2,3	0	5	5	0	0
0,1	6	14	11	3	0
-2,-1	1	7	13	1	0
-4,-3	1	4	7	5	2
-6,-5	1	5	2	0	1
-8,-7	0	1	2	0	0
-10,-9	0	1	0	0	0
≤-11	0	2	1	0	0

After Brower et al. 1988

May

Figure 21e

Air Temperature/Wind Speed

Ostrov Vrangelja

4288 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥10	+	0	+	0	0
8,9	0	+	0	0	0
6,7	+	+	+	+	0
4,5	1	2	1	+	+
2,3	6	12	4	+	+
0,1	7	17	5	1	+
-2,-1	7	14	5	+	+
-4,-3	3	6	2	+	+
-6,-5	1	2	1	+	+
-8,-7	+	+	+	+	+
≤-9	0	+	+	0	0

Mys Shmidta

4502 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥10	1	2	1	0	0
8,9	1	1	1	+	+
6,7	1	2	1	+	0
4,5	1	5	2	+	0
2,3	3	13	6	1	+
0,1	2	17	5	+	+
-2,-1	3	15	4	+	+
-4,-3	1	5	1	+	+
-6,-5	+	2	1	+	+
-8,-7	+	+	+	+	0
≤-9	0	0	0	+	0

Ostrov Kolychino

2764 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥10	+	1	2	0	0
8,9	+	1	2	+	0
6,7	1	2	3	+	0
4,5	1	4	5	1	0
2,3	2	9	8	1	0
0,1	3	12	6	+	0
-2,-1	2	14	5	+	0
-4,-3	1	5	2	+	+
-6,-5	1	2	1	+	0
-8,-7	0	1	+	0	0
≤-9	0	+	+	0	0

Mys Uelen

4479 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥12	+	+	+	0	0
10,11	+	+	+	+	0
8,9	+	1	1	0	0
6,7	1	2	2	1	0
4,5	2	4	4	1	+
2,3	6	12	8	3	+
0,1	5	10	7	2	+
-2,-1	3	9	6	1	+
-4,-3	1	2	2	+	0
-6,-5	+	+	+	+	0
≤-7	0	0	0	0	0

Tin City

19939 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥12	1	1	+	+	0
10,11	1	2	1	+	0
8,9	1	2	2	+	0
6,7	2	5	4	+	+
4,5	2	5	5	1	+
2,3	2	8	11	2	0
0,1	2	9	14	3	+
-2,-1	1	4	6	1	+
-4,-3	+	1	2	1	0
-6,-5	+	+	+	+	0
≤-7	0	+	0	0	0

Kotzebue

20512 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥16	+	2	1	+	0
14,15	+	2	1	+	0
12,13	+	4	2	+	0
10,11	1	6	4	+	0
8,9	1	5	4	+	0
6,7	1	8	6	+	0
4,5	1	7	5	+	0
2,3	1	10	7	1	0
0,1	1	7	7	1	+
-2,-1	+	1	2	+	0
≤-3	+	+	+	+	0

Cape Lisburne

19396 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥12	+	1	1	+	+
10,11	1	1	1	1	+
8,9	1	2	2	1	+
6,7	4	4	2	1	+
4,5	4	5	2	1	+
2,3	8	11	3	1	+
0,1	8	15	5	+	+
-2,-1	2	7	2	+	+
-4,-3	1	1	1	+	+
-6,-5	+	+	+	0	0
≤-7	+	+	+	0	0

Point Lay

3124 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥14	+	2	1	+	0
12,13	1	2	1	+	0
10,11	1	4	1	+	0
8,9	1	5	2	+	0
6,7	2	7	2	+	0
4,5	2	8	2	1	+
2,3	3	12	5	1	+
0,1	3	12	5	1	0
-2,-1	1	4	2	+	0
-4,-3	+	1	1	+	+
≤-5	+	1	+	0	0

Barrow

17498 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥10	+	1	1	0	0
8,9	+	1	+	+	0
6,7	+	2	1	+	0
4,5	+	3	2	+	0
2,3	1	8	6	+	0
0,1	1	23	15	+	0
-2,-1	1	12	9	+	+
-4,-3	+	5	5	+	0
-6,-5	+	1	1	+	0
-8,-7	+	+	+	+	0
≤-9	+	+	+	+	0

Marine Area A

100 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥10	0	0	0	0	0
8,9	0	1	1	0	0
6,7	1	3	0	0	0
4,5	1	3	2	0	0
2,3	0	2	11	0	0
0,1	1	17	13	1	1
-2,-1	1	18	4	1	0
-4,-3	3	9	0	2	0
-6,-5	1	2	1	0	0
-8,-7	0	0	0	0	0
≤-9	0	0	0	0	0

Marine Area B

No Data Available

Marine Area D

514 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥14	0	+	+	0	0
12,13	0	+	0	+	0
10,11	+	2	+	0	+
8,9	1	3	2	+	0
6,7	3	6	4	+	0
4,5	3	13	8	+	0
2,3	3	13	11	2	+
0,1	1	9	7	2	0
-2,-1	+	1	1	1	0
-4,-3	0	0	+	0	0
≤-5	0	0	0	0	0

After Brower et al. 1988

June

Figure 21f

Air Temperature/Wind Speed

Ostrov Vrangelja

4253 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥12	0	+	+	+	0
10,11	+	+	+	0	0
8,9	+	1	1	+	0
6,7	1	2	1	+	0
4,5	2	7	4	+	0
2,3	8	21	9	1	+
0,1	9	14	5	+	+
-2,-1	5	6	2	+	0
-4,-3	+	1	+	+	0
-6,-5	0	0	0	0	0
≤-7	0	0	0	0	0

Mys Shmidta

4499 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥14	1	2	1	+	0
12,13	1	2	1	+	0
10,11	+	1	1	+	0
8,9	1	2	1	+	0
6,7	1	5	2	+	0
4,5	2	9	3	+	0
2,3	4	23	9	1	0
0,1	2	12	6	1	0
-2,-1	1	3	2	+	0
-4,-3	+	+	0	0	0
≤-5	0	0	0	0	0

Ostrov Kolychino

2581 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥14	+	1	2	+	+
12,13	1	2	2	+	0
10,11	+	2	3	1	+
8,9	1	3	6	1	0
6,7	1	4	6	2	0
4,5	2	6	6	1	+
2,3	3	12	6	1	0
0,1	2	11	3	+	+
-2,-1	1	6	3	+	0
-4,-3	+	+	0	0	0
≤-5	0	0	0	0	0

Mys Uelen

4497 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥14	+	1	1	+	0
12,13	+	1	2	1	0
10,11	1	2	2	1	0
8,9	1	3	5	3	+
6,7	3	5	7	5	1
4,5	4	8	6	4	1
2,3	4	11	8	1	+
0,1	1	3	2	+	+
-2,-1	+	+	+	+	0
-4,-3	0	0	0	0	0
≤-5	0	0	0	0	0

Tin City

20635 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥16	1	1	+	0	0
14,15	+	1	1	0	0
12,13	1	3	2	+	0
10,11	2	5	3	+	+
8,9	2	6	7	1	+
6,7	2	10	15	2	+
4,5	1	7	12	2	+
2,3	+	3	6	1	+
0,1	+	+	2	+	+
-2,-1	+	+	+	+	0
≤-3	0	0	0	0	0

Kotzebue

21130 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥20	+	2	1	+	0
18,19	+	2	1	+	0
16,17	1	5	3	+	0
14,15	1	7	4	+	0
12,13	1	11	8	1	0
10,11	1	11	11	1	+
8,9	+	5	6	1	0
6,7	+	4	6	1	+
4,5	+	1	3	1	+
2,3	+	+	1	+	0
≤1	+	+	+	+	0

Cape Lisburne

19393 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥16	+	1	1	+	0
14,15	1	1	1	+	+
12,13	2	2	2	1	+
10,11	3	5	4	2	+
8,9	4	6	4	2	+
6,7	5	9	5	1	+
4,5	4	7	3	1	+
2,3	4	9	3	+	+
0,1	2	4	1	+	+
-2,-1	+	+	+	0	0
≤-3	0	0	0	0	0

Point Lay

3015 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥18	+	1	1	+	0
16,17	+	2	1	+	0
14,15	1	2	1	+	0
12,13	2	5	2	+	0
10,11	3	9	4	+	0
8,9	2	7	5	+	0
6,7	2	9	5	1	0
4,5	2	8	3	+	0
2,3	2	7	4	+	0
0,1	1	3	1	+	0
≤-1	+	+	+	0	0

Barrow

18772 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥12	+	2	2	+	0
10,11	+	2	2	+	0
8,9	+	3	2	+	0
6,7	1	5	4	+	0
4,5	1	6	5	+	0
2,3	1	12	10	+	+
0,1	1	19	14	+	0
-2,-1	1	5	2	+	0
-4,-3	+	+	+	0	0
-6,-5	0	0	0	0	0
≤-7	0	0	0	0	0

Marine Area A

368 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥12	+	1	0	+	0
10,11	1	1	+	+	+
8,9	0	1	2	0	0
6,7	1	5	3	1	0
4,5	2	5	7	1	0
2,3	1	11	11	1	0
0,1	2	14	16	1	0
-2,-1	1	5	3	1	+
-4,-3	1	1	1	0	0
-6,-5	0	0	0	0	0
≤-7	0	0	0	0	0

Marine Area B

2940 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥12	+	+	+	+	0
10,11	+	+	1	1	0
8,9	1	1	1	+	+
6,7	1	4	4	1	0
4,5	2	7	6	1	0
2,3	3	12	11	1	+
0,1	4	18	12	1	+
-2,-1	1	4	2	+	0
-4,-3	0	+	0	0	0
-6,-5	0	0	0	0	0
≤-7	0	0	0	0	0

Marine Area D

2710 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥16	+	+	1	+	0
14,15	+	1	1	+	0
12,13	1	2	2	+	+
10,11	1	4	4	1	+
8,9	2	6	6	2	+
6,7	2	8	12	3	+
4,5	2	8	10	2	+
2,3	1	4	5	2	+
0,1	+	2	2	+	+
-2,-1	+	+	+	+	0
≤-3	0	0	0	0	0

July

After Brower et al. 1988

Figure 21g

Air Temperature/Wind Speed

Ostrov Vrangelja

4252 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥12	0	+	+	0	0
10,11	+	+	+	+	0
8,9	+	1	+	+	0
6,7	1	3	1	+	0
4,5	3	7	2	1	+
2,3	8	14	8	2	+
0,1	7	12	5	1	+
-2,-1	5	8	3	1	+
-4,-3	1	2	1	+	+
-6,-5	+	+	+	0	0
≤-7	0	0	0	0	0

Mys Shmidta

4564 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥12	1	2	1	+	0
10,11	+	2	+	0	0
8,9	1	2	1	+	0
6,7	1	4	2	+	+
4,5	2	8	3	+	0
2,3	3	16	9	1	+
0,1	2	12	7	1	+
-2,-1	2	8	5	1	+
-4,-3	+	1	1	+	0
-6,-5	+	+	0	0	0
≤-7	0	0	0	0	0

Ostrov Kolychino

2530 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥14	+	+	1	0	0
12,13	+	1	1	+	0
10,11	+	2	3	+	0
8,9	1	3	5	1	+
6,7	1	5	6	1	+
4,5	1	8	6	2	+
2,3	2	11	8	1	+
0,1	1	9	7	1	+
-2,-1	1	6	3	+	+
-4,-3	+	+	+	0	0
≤-5	0	0	0	0	0

Mys Uelen

4515 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥14	+	+	+	+	0
12,13	+	+	1	+	+
10,11	+	1	2	+	+
8,9	1	2	5	2	+
6,7	3	6	7	3	1
4,5	5	12	11	3	1
2,3	4	10	12	2	+
0,1	1	2	2	+	+
-2,-1	+	+	0	+	0
-4,-3	0	0	0	0	0
≤-5	0	0	0	0	0

Tin City

20765 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥16	+	+	+	0	0
14,15	+	1	1	+	0
12,13	1	2	2	+	0
10,11	1	4	5	1	+
8,9	2	7	9	1	+
6,7	2	12	18	3	+
4,5	1	5	10	2	+
2,3	+	3	4	1	+
0,1	+	1	+	+	+
-2,-1	+	0	0	0	0
≤-3	0	0	+	0	0

Kotzebue

21792 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥20	+	+	+	+	0
18,19	+	1	+	+	0
16,17	+	2	2	+	0
14,15	+	4	3	+	0
12,13	1	9	8	+	+
10,11	1	13	13	1	+
8,9	1	8	9	1	+
6,7	1	6	7	1	+
4,5	+	2	2	+	+
2,3	+	1	1	+	0
≤1	0	+	+	+	0

Cape Lisburne

20220 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥16	+	1	+	+	0
14,15	+	1	+	+	0
12,13	2	3	1	+	+
10,11	3	5	3	1	+
8,9	4	7	5	1	+
6,7	5	10	7	1	+
4,5	3	9	6	1	+
2,3	2	7	7	1	+
0,1	1	1	2	+	0
-2,-1	+	+	+	+	0
≤-3	0	0	0	0	0

Point Lay

3273 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥16	1	2	+	+	0
14,15	+	2	+	+	0
12,13	1	5	1	+	0
10,11	2	7	3	+	0
8,9	2	8	3	1	0
6,7	3	10	5	1	+
4,5	3	9	5	1	+
2,3	2	8	3	1	+
0,1	1	5	2	+	0
-2,-1	+	1	1	+	0
≤-3	+	+	+	0	0

Barrow

19325 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥12	+	2	1	+	0
10,11	+	2	1	+	0
8,9	+	3	2	+	0
6,7	+	5	4	+	+
4,5	1	7	5	+	+
2,3	1	10	8	1	0
0,1	1	14	13	1	0
-2,-1	1	7	5	+	0
-4,-3	+	2	2	+	0
-6,-5	+	+	+	0	0
≤-7	0	0	0	0	0

Marine Area A

677 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥12	+	+	+	0	0
10,11	+	1	+	0	0
8,9	+	2	3	0	0
6,7	1	3	3	1	0
4,5	2	5	4	+	0
2,3	2	10	8	1	+
0,1	5	15	9	2	+
-2,-1	1	5	6	1	+
-4,-3	1	4	1	+	0
-6,-5	+	1	+	+	0
≤-7	0	+	0	0	0

Marine Area B

4808 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥12	+	1	+	+	0
10,11	+	1	1	+	0
8,9	1	1	1	+	+
6,7	1	4	3	1	+
4,5	2	6	5	1	+
2,3	2	9	9	1	+
0,1	4	14	12	2	+
-2,-1	1	4	5	1	+
-4,-3	+	1	1	+	+
-6,-5	+	+	+	+	0
≤-7	0	+	0	0	0

Marine Area D

2477 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥16	+	+	+	0	0
14,15	+	1	1	0	0
12,13	1	2	2	+	0
10,11	1	4	5	1	+
8,9	2	6	8	2	+
6,7	2	8	13	4	+
4,5	1	7	9	3	+
2,3	1	4	4	1	+
0,1	1	2	2	1	+
-2,-1	+	+	+	+	+
≤-3	+	+	+	+	0

August

After Brower et al. 1988

Figure 21h

Air Temperature/Wind Speed

Ostrov Vrangelje

4070 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥8	0	0	0	0	0
6,7	+	+	+	+	0
4,5	1	1	1	+	0
2,3	2	5	4	1	+
0,1	4	7	6	1	+
-2,-1	6	12	10	1	+
-4,-3	4	8	6	2	+
-6,-5	1	3	3	1	+
-8,-7	1	1	1	+	+
-10,-9	+	1	+	+	+
≤-11	+	+	+	+	+

Mys Shmidta

4315 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥8	+	1	+	0	0
6,7	+	1	1	+	0
4,5	1	3	1	0	0
2,3	3	8	6	+	+
0,1	2	10	6	1	+
-2,-1	4	13	11	2	+
-4,-3	2	6	5	2	+
-6,-5	1	2	2	1	+
-8,-7	1	1	1	+	+
-10,-9	+	+	+	+	+
≤-11	1	+	+	+	+

Ostrov Kolychino

2431 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥10	+	+	+	+	0
8,9	+	+	1	+	0
6,7	+	2	2	+	0
4,5	1	3	5	1	+
2,3	2	9	12	3	+
0,1	2	10	9	1	+
-2,-1	2	9	10	2	+
-4,-3	1	4	3	1	+
-6,-5	+	1	1	+	0
-8,-7	+	+	+	0	0
≤-9	+	0	0	0	0

Mys Uelen

4350 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥12	0	0	+	+	+
10,11	+	+	+	+	0
8,9	+	+	1	+	+
6,7	+	2	2	1	+
4,5	2	6	9	3	+
2,3	4	13	18	7	1
0,1	2	5	7	3	+
-2,-1	1	3	4	1	+
-4,-3	+	1	1	+	0
-6,-5	+	+	+	+	0
≤-7	+	+	+	+	0

Tin City

19412 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥14	+	+	+	+	0
12,13	+	+	+	+	0
10,11	1	1	1	+	+
8,9	1	3	3	1	+
6,7	2	6	9	2	+
4,5	2	7	11	2	+
2,3	2	8	12	3	+
0,1	1	5	8	2	+
-2,-1	+	2	3	1	+
-4,-3	+	+	1	1	+
≤-5	+	+	+	+	0

Kotzebue

21063 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥14	+	+	1	+	0
12,13	+	1	1	+	0
10,11	+	4	3	+	0
8,9	1	5	5	+	0
6,7	1	11	11	1	+
4,5	1	8	7	1	+
2,3	1	8	7	1	+
0,1	1	5	5	1	+
-2,-1	+	2	2	+	+
-4,-3	+	1	1	+	0
≤-5	+	1	+	+	0

Cape Lisburne

19462 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥12	+	+	+	+	0
10,11	+	1	1	+	+
8,9	1	2	1	+	0
6,7	3	5	3	1	+
4,5	3	6	5	1	+
2,3	4	10	9	1	+
0,1	3	9	11	2	+
-2,-1	1	3	4	1	+
-4,-3	+	1	2	+	+
-6,-5	+	+	1	+	+
≤-7	0	+	+	+	0

Point Lay

3220 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥10	1	2	1	+	0
8,9	1	2	+	0	0
6,7	1	4	1	+	0
4,5	2	5	2	+	0
2,3	3	10	5	1	0
0,1	3	12	8	1	0
-2,-1	2	9	5	1	+
-4,-3	1	4	3	1	0
-6,-5	+	2	1	+	0
-8,-7	+	1	1	+	0
≤-9	+	1	1	+	0

Barrow

18708 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥8	+	1	+	0	0
6,7	+	1	1	+	0
4,5	+	2	1	+	0
2,3	+	5	5	+	+
0,1	1	13	11	1	+
-2,-1	1	11	12	1	+
-4,-3	1	8	8	1	+
-6,-5	+	3	4	+	0
-8,-7	+	3	2	+	0
-10,-9	+	1	1	0	0
≤-11	+	1	1	+	0

Marine Area A

838 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥8	0	+	+	+	0
6,7	+	1	1	0	0
4,5	1	2	2	1	+
2,3	1	5	8	2	+
0,1	1	8	12	5	+
-2,-1	2	6	9	2	+
-4,-3	2	2	5	1	0
-6,-5	2	3	2	1	0
-8,-7	3	2	1	1	0
-10,-9	1	1	1	+	0
≤-11	1	1	1	+	0

Marine Area B

2463 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥8	+	+	1	+	0
6,7	+	1	1	+	+
4,5	1	1	2	1	0
2,3	1	3	5	1	+
0,1	3	10	13	4	+
-2,-1	2	10	10	2	+
-4,-3	1	6	6	1	+
-6,-5	+	2	3	+	+
-8,-7	1	1	2	+	0
-10,-9	+	+	1	0	0
≤-11	0	+	1	+	+

Marine Area D

2213 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥12	+	1	+	0	0
10,11	+	1	+	+	+
8,9	+	2	2	1	0
6,7	1	4	8	2	+
4,5	2	6	11	4	1
2,3	1	6	8	5	1
0,1	3	5	6	3	1
-2,-1	1	3	2	1	+
-4,-3	+	1	2	1	0
-6,-5	+	+	1	+	0
≤-7	+	0	+	0	0

After Brower et al. 1988

September

Figure 21i

Air Temperature/Wind Speed

Ostrov Vrangelja

4248 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥0	1	2	2	+	0
-2,-1	1	3	3	+	+
-4,-3	1	5	5	1	+
-6,-5	1	4	5	1	+
-8,-7	2	5	7	2	1
-10,-9	1	3	4	1	1
-12,-11	2	4	3	1	+
-14,-13	2	3	4	1	+
-16,-15	1	2	3	1	+
-18,-17	1	2	2	1	+
≤-19	2	1	1	1	+

Mys Shmidta

4565 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥0	+	1	1	+	0
-2,-1	1	4	3	+	+
-4,-3	1	4	5	2	+
-6,-5	1	3	6	2	1
-8,-7	2	5	6	2	1
-10,-9	1	3	3	1	+
-12,-11	2	3	3	1	1
-14,-13	2	3	3	2	+
-16,-15	1	2	2	1	+
-18,-17	1	2	2	+	+
≤-19	3	2	1	1	+

Ostrov Kolychino

2709 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥4	+	0	+	+	0
2,3	+	1	1	+	+
0,1	+	2	3	1	+
-2,-1	1	5	8	4	1
-4,-3	1	5	7	5	1
-6,-5	1	3	7	4	2
-8,-7	1	6	6	2	1
-10,-9	+	2	2	1	+
-12,-11	+	2	2	1	+
-14,-13	+	1	2	+	+
≤-15	2	3	2	1	+

Mys Uelen

4532 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥6	0	+	+	+	+
4,5	+	+	1	1	+
2,3	1	2	5	2	1
0,1	1	3	6	2	+
-2,-1	1	6	10	7	2
-4,-3	1	3	7	6	1
-6,-5	1	3	4	4	1
-8,-7	1	3	3	2	1
-10,-9	+	1	1	1	+
-12,-11	+	1	1	+	+
≤-13	1	2	1	+	0

Tin City

19607 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥6	+	+	+	+	+
4,5	+	1	1	1	+
2,3	1	2	4	1	+
0,1	1	5	7	3	+
-2,-1	2	5	8	2	+
-4,-3	2	6	9	4	+
-6,-5	1	4	5	2	+
-8,-7	1	3	4	2	+
-10,-9	+	2	3	1	+
-12,-11	+	1	1	+	+
≤-13	+	1	1	+	+

Kotzebue

21788 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥4	+	1	2	+	0
2,3	+	2	4	1	0
0,1	1	6	8	1	+
-2,-1	1	5	5	1	0
-4,-3	1	7	6	2	+
-6,-5	1	5	4	1	+
-8,-7	1	6	4	1	+
-10,-9	+	5	3	1	+
-12,-11	+	3	2	+	+
-14,-13	+	3	1	+	0
≤-15	+	5	1	+	0

Cape Lisburne

20259 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥4	+	+	1	1	+
2,3	1	1	2	1	+
0,1	2	3	3	1	+
-2,-1	2	4	5	2	+
-4,-3	3	6	8	3	+
-6,-5	2	5	5	2	+
-8,-7	1	4	5	1	+
-10,-9	1	4	3	1	+
-12,-11	+	2	2	1	+
-14,-13	+	2	3	+	+
≤-15	+	2	3	+	+

Point Lay

2966 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥0	1	4	3	1	0
-2,-1	1	4	3	1	+
-4,-3	2	5	3	1	+
-6,-5	2	4	3	1	0
-8,-7	3	6	3	1	0
-10,-9	1	4	3	+	+
-12,-11	1	4	2	1	+
-14,-13	1	4	3	1	0
-16,-15	1	3	2	1	0
-18,-17	1	3	2	1	0
≤-19	1	6	4	1	0

Barrow

19089 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥0	+	1	3	+	+
-2,-1	+	2	4	1	+
-4,-3	1	4	6	1	+
-6,-5	1	4	4	1	0
-8,-7	1	7	6	1	+
-10,-9	+	6	5	1	+
-12,-11	+	3	3	+	0
-14,-13	+	4	4	+	0
-16,-15	+	3	3	+	0
-18,-17	+	3	3	+	0
≤-19	1	7	3	+	0

Marine Area A

280 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-2	1	1	7	3	0
-4,-3	1	3	2	1	+
-6,-5	0	2	1	1	0
-8,-7	1	1	2	1	+
-10,-9	1	2	6	3	+
-12,-11	1	4	2	2	+
-14,-13	2	9	2	2	0
-16,-15	0	7	3	2	0
-18,-17	+	4	3	0	0
-20,-19	0	1	1	0	0
≤-21	1	6	4	1	0

Marine Area B

1008 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-4	1	5	8	3	+
-6,-5	1	3	2	1	1
-8,-7	1	2	2	+	+
-10,-9	1	3	3	1	+
-12,-11	1	2	2	1	+
-14,-13	1	3	3	+	+
-16,-15	+	5	3	1	+
-18,-17	1	3	4	+	0
-20,-19	1	4	3	+	0
-22,-21	+	3	1	+	0
≤-23	2	10	3	0	0

Marine Area D

865 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥6	0	+	+	+	0
4,5	0	+	2	1	0
2,3	+	3	5	2	1
0,1	1	2	5	6	2
-2,-1	1	3	6	4	1
-4,-3	1	3	6	6	2
-6,-5	+	2	4	3	1
-8,-7	+	3	2	2	1
-10,-9	+	1	1	1	+
-12,-11	+	1	2	2	1
≤-13	+	1	2	+	+

October

After Brower et al. 1988

Figure 21j

Air Temperature/Wind Speed

Ostrov Vrangelje

4118 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-6	1	2	4	2	+
-8,-7	1	2	5	1	+
-10,-9	+	1	2	1	+
-12,-11	1	2	3	1	1
-14,-13	1	3	4	2	+
-16,-15	1	3	4	2	1
-18,-17	2	3	5	3	1
-20,-19	1	3	3	2	1
-22,-21	1	3	4	2	1
-24,-23	1	3	2	1	+
≤-25	2	3	1	+	+

Mys Shmidta

4342 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-8	1	4	8	3	1
-10,-9	+	1	2	+	+
-12,-11	1	2	2	1	+
-14,-13	1	2	3	2	1
-16,-15	1	2	3	2	1
-18,-17	2	3	4	2	1
-20,-19	1	2	3	2	+
-22,-21	1	3	3	2	1
-24,-23	1	2	3	2	+
-26,-25	2	2	3	1	+
≤-27	4	4	3	1	+

Ostrov Kolychino

2577 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-4	+	2	5	2	1
-6,-5	+	1	4	2	1
-8,-7	+	2	6	2	1
-10,-9	+	1	3	1	+
-12,-11	1	2	4	1	+
-14,-13	+	2	4	2	1
-16,-15	1	3	4	1	+
-18,-17	1	4	4	1	+
-20,-19	+	2	2	1	+
-22,-21	1	3	2	1	0
≤-23	3	7	4	1	0

Mys Uelen

4328 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥0	+	+	1	2	2
-2,-1	+	1	3	2	1
-4,-3	1	2	4	3	1
-6,-5	1	3	4	4	1
-8,-7	1	3	5	4	1
-10,-9	+	2	3	2	+
-12,-11	1	2	3	2	+
-14,-13	1	3	3	2	+
-16,-15	+	3	3	1	+
-18,-17	1	2	3	1	+
≤-19	3	4	4	1	+

Tin City

19014 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥0	+	1	2	2	+
-2,-1	1	2	2	1	+
-4,-3	1	2	4	2	+
-6,-5	1	2	4	2	+
-8,-7	1	2	6	3	+
-10,-9	1	3	6	3	1
-12,-11	1	2	4	2	+
-14,-13	+	2	6	3	+
-16,-15	+	1	4	2	+
-18,-17	+	1	3	1	+
≤-19	+	1	4	2	+

Kotzebue

21084 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-4	1	2	5	3	+
-6,-5	1	2	3	1	+
-8,-7	1	3	5	2	+
-10,-9	1	4	4	2	+
-12,-11	1	4	3	1	+
-14,-13	1	5	4	2	+
-16,-15	1	4	3	1	+
-18,-17	1	5	2	1	+
-20,-19	1	4	2	1	+
-22,-21	+	2	1	+	+
≤-23	3	8	2	+	+

Cape Lisburne

19420 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-4	2	3	5	4	1
-6,-5	1	2	2	1	+
-8,-7	1	3	3	1	+
-10,-9	1	4	3	1	+
-12,-11	1	3	3	1	+
-14,-13	1	5	4	1	+
-16,-15	1	5	4	1	+
-18,-17	1	5	4	1	+
-20,-19	1	4	5	1	+
-22,-21	1	2	2	1	0
≤-23	1	3	2	+	+

Point Lay

3103 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-8	1	6	5	2	+
-10,-9	1	2	2	+	0
-12,-11	[illegible]	3	1	1	+
-14,-13	1	4	2	1	+
-16,-15	1	3	3	1	0
-18,-17	1	4	4	1	+
-20,-19	1	3	3	2	+
-22,-21	1	3	3	2	+
-24,-23	1	3	3	2	+
-26,-25	1	2	2	1	+
≤-27	2	7	6	1	+

Barrow

18466 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-10	1	5	8	2	+
-12,-11	+	1	2	1	0
-14,-13	+	3	4	1	+
-16,-15	+	3	4	1	+
-18,-17	1	5	5	1	+
-20,-19	+	5	4	1	0
-22,-21	+	5	4	1	0
-24,-23	+	6	5	+	0
-26,-25	+	4	2	+	0
-28,-27	1	4	1	0	0
≤-29	1	5	1	0	0

Marine Area A

114 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-14	1	1	6	11	0
-16,-15	0	0	1	3	0
-18,-17	0	3	1	2	0
-20,-19	0	4	1	0	0
-22,-21	2	1	0	0	0
-24,-23	9	6	0	0	0
-26,-25	7	4	2	0	0
-28,-27	7	5	0	0	0
-30,-29	4	4	0	0	0
-32,-31	2	3	0	0	0
≤-33	11	2	0	0	0

Marine Area B

838 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-12	1	3	2	1	0
-14,-13	3	2	1	+	0
-16,-15	6	2	2	+	+
-18,-17	3	1	1	1	+
-20,-19	3	2	1	+	+
-22,-21	4	2	2	2	+
-24,-23	4	4	3	1	+
-26,-25	3	4	3	2	0
-28,-27	5	3	5	1	0
-30,-29	1	3	4	0	0
≤-31	+	6	3	+	0

Marine Area D

89 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥2	0	0	2	1	1
0,1	0	1	1	1	4
-2,-1	0	2	1	6	3
-4,-3	0	0	3	3	1
-6,-5	0	1	2	4	0
-8,-7	1	0	1	3	0
-10,-9	0	2	3	1	1
-12,-11	0	0	9	4	1
-14,-13	0	1	8	1	0
-16,-15	0	0	11	3	0
≤-17	0	0	4	2	0

After Brower et al. 1988

November

Figure 21k

Air Temperature/Wind Speed

Ostrov Vrangelje

4183 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-12	1	3	2	1	0
-14,-13	1	1	1	+	+
-16,-15	1	2	2	1	+
-18,-17	2	3	4	1	+
-20,-19	2	2	2	1	+
-22,-21	3	3	4	2	1
-24,-23	3	5	4	2	1
-26,-25	4	5	3	2	1
-28,-27	5	5	3	1	+
-30,-29	2	2	1	+	+
≤-31	4	1	1	+	0

Mys Shmidta

4427 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-14	1	3	2	1	+
-16,-15	1	2	1	+	+
-18,-17	2	3	3	1	+
-20,-19	1	2	2	1	+
-22,-21	2	2	3	1	+
-24,-23	2	3	4	1	+
-26,-25	2	3	4	2	1
-28,-27	3	5	5	1	+
-30,-29	1	3	3	1	+
-32,-31	2	2	3	1	+
≤-33	6	3	2	1	+

Ostrov Kolychino

2548 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-12	1	3	7	2	+
-14,-13	+	1	2	+	+
-16,-15	+	2	2	+	+
-18,-17	1	4	5	1	+
-20,-19	1	2	2	+	+
-22,-21	1	3	4	1	+
-24,-23	1	5	5	1	+
-26,-25	1	4	4	1	0
-28,-27	2	6	4	1	+
-30,-29	2	4	2	+	0
≤-31	3	7	2	+	0

Mys Uelen

4443 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-10	1	4	6	4	2
-12,-11	1	2	2	1	+
-14,-13	1	2	2	1	+
-16,-15	1	2	2	1	+
-18,-17	2	3	5	1	+
-20,-19	1	2	3	1	+
-22,-21	2	3	4	1	+
-24,-23	2	3	4	1	+
-26,-25	2	4	3	1	0
-28,-27	3	3	2	+	0
≤-29	3	3	2	+	0

Tin City

19131 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-8	2	5	7	3	1
-10,-9	1	1	2	1	+
-12,-11	1	1	2	1	+
-14,-13	1	1	4	2	+
-16,-15	1	1	3	2	+
-18,-17	1	1	5	3	+
-20,-19	1	1	5	3	+
-22,-21	+	1	4	3	+
-24,-23	1	1	5	4	+
-26,-25	+	1	3	2	+
≤-27	+	1	5	3	+

Kotzebue

21787 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-10	1	4	9	6	1
-12,-11	+	1	2	1	+
-14,-13	1	3	2	1	+
-16,-15	1	3	2	1	+
-18,-17	1	3	2	1	+
-20,-19	1	4	2	1	+
-22,-21	1	4	2	1	+
-24,-23	1	4	2	1	+
-26,-25	1	3	1	+	+
-28,-27	2	4	1	+	+
≤-29	6	11	2	+	+

Cape Lisburne

19244 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-10	2	4	4	4	1
-12,-11	1	1	1	+	+
-14,-13	1	3	1	+	+
-16,-15	1	3	2	+	+
-18,-17	1	4	3	1	+
-20,-19	2	5	5	1	+
-22,-21	2	4	4	1	+
-24,-23	2	5	4	1	+
-26,-25	2	3	2	+	+
-28,-27	2	3	2	+	+
≤-29	3	4	1	+	0

Point Lay

3338 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-16	2	8	5	2	+
-18,-17	1	2	[illegible]	[illegible]	+
-20,-19	1	2	[illegible]	[illegible]	0
-22,-21	1	2	2	[illegible]	+
-24,-23	1	4	4	[illegible]	+
-26,-25	1	3	3	1	+
-28,-27	1	4	3	1	+
-30,-29	1	3	3	1	+
-32,-31	1	3	2	+	+
-34,-33	1	3	2	+	0
≤-35	4	7	5	+	0

Barrow

19055 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-16	+	4	6	1	+
-18,-17	+	3	3	1	+
-20,-19	+	4	4	1	+
-22,-21	1	4	4	1	+
-24,-23	1	6	5	1	+
-26,-25	1	5	3	+	0
-28,-27	1	7	3	+	0
-30,-29	1	7	2	+	0
-32,-31	1	5	1	0	0
-34,-33	1	5	1	0	0
≤-35	2	7	1	0	0

Marine Area A

243 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-16	2	1	+	0	0
-18,-17	0	3	+	+	0
-20,-19	1	3	2	0	0
-22,-21	4	4	3	0	0
-24,-23	3	4	2	+	0
-26,-25	5	8	4	0	0
-28,-27	9	6	3	+	0
-30,-29	2	4	+	0	0
-32,-31	2	7	2	0	+
-34,-33	3	5	0	0	0
≤-35	1	5	0	0	0

Marine Area B

582 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥-14	12	7	1	0	0
-16,-15	1	2	+	+	0
-18,-17	2	1	+	0	0
-20,-19	2	2	1	1	+
-22,-21	1	3	1	1	0
-24,-23	4	4	1	+	0
-26,-25	9	4	2	+	0
-28,-27	11	3	1	0	0
-30,-29	7	1	+	0	0
-32,-31	2	1	2	0	0
≤-33	4	7	1	0	+

Marine Area D

15 Wind Speed (knots)

TEMP (°C)	0-3	4-10	11-21	22-33	≥34
≥2	0	0	7	0	0
0,1	0	0	7	0	0
-2,-1	0	0	7	0	0
-4,-3	0	0	7	20	0
-6,-5	0	7	0	7	0
-8,-7	0	0	0	0	0
-10,-9	0	7	0	0	0
-12,-11	0	0	7	7	0
-14,-13	0	0	0	0	0
-16,-15	0	0	0	0	0
≤-17	0	0	13	7	0

After Brower et al. 1988

December

Figure 21l

Graphs: Air temperature/wind direction

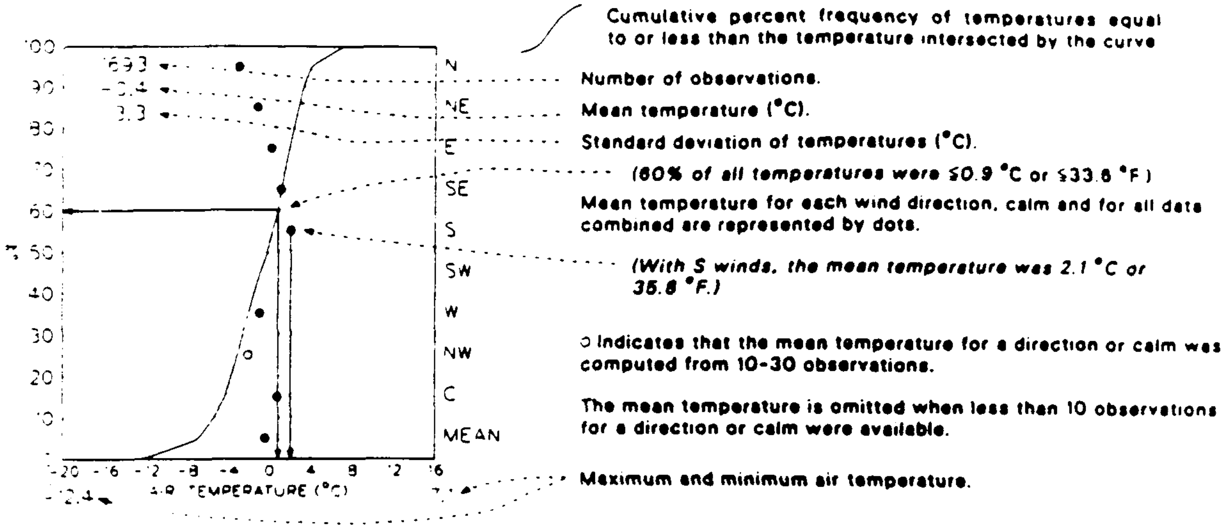
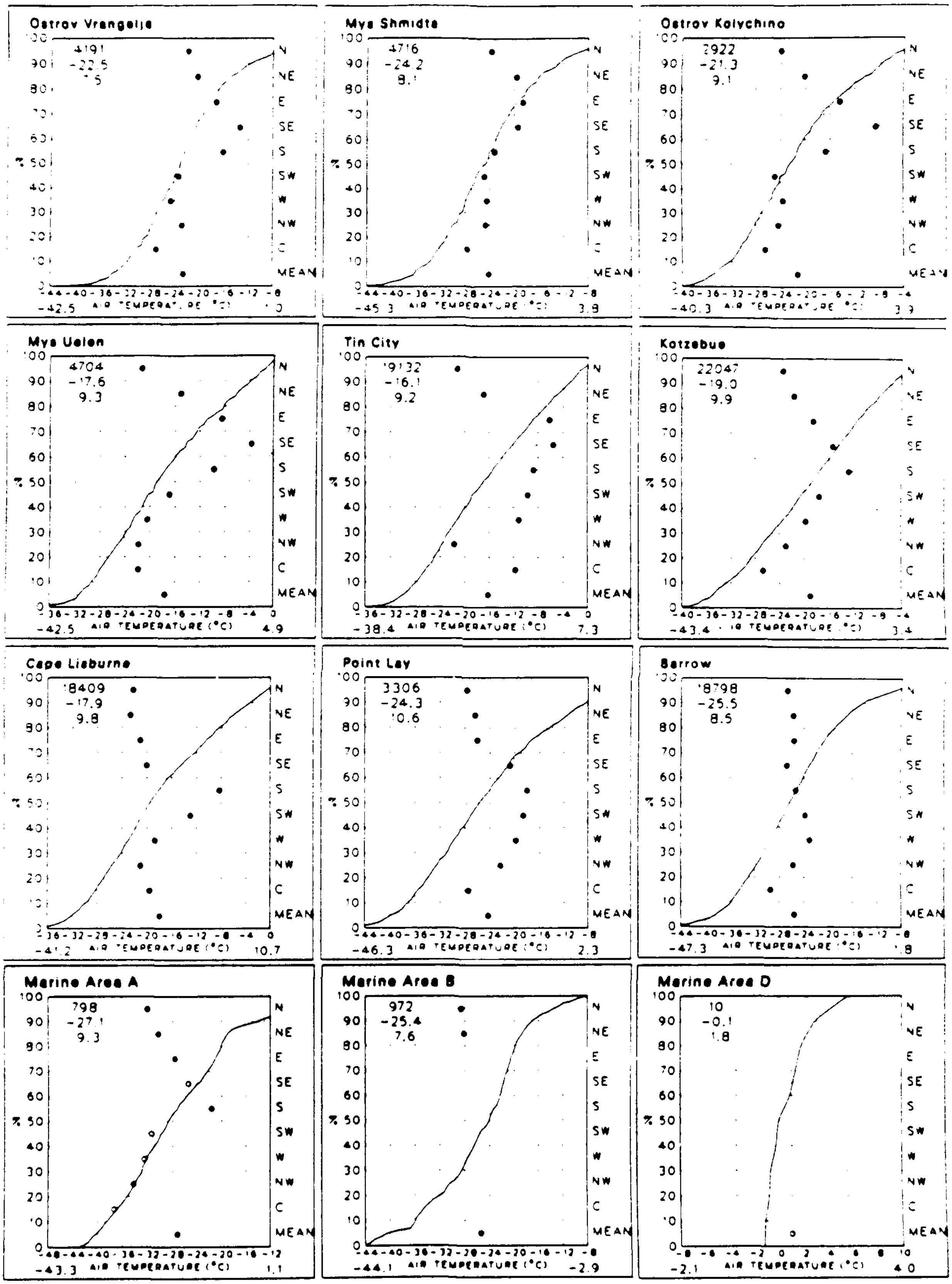


Figure 22

Air Temperature/Wind Direction

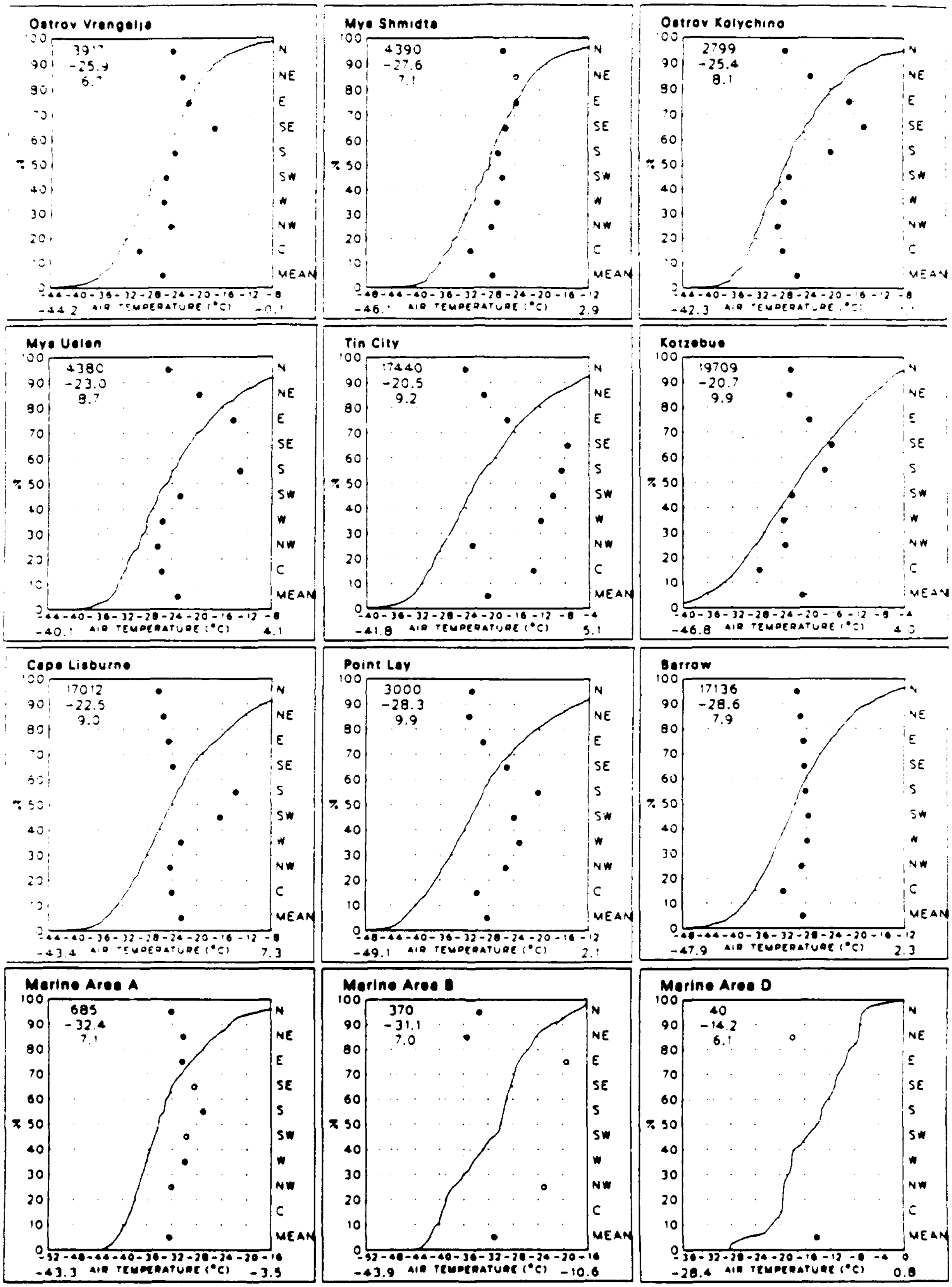


After Brower et al. 1988

January

Figure 22a

Air Temperature/Wind Direction

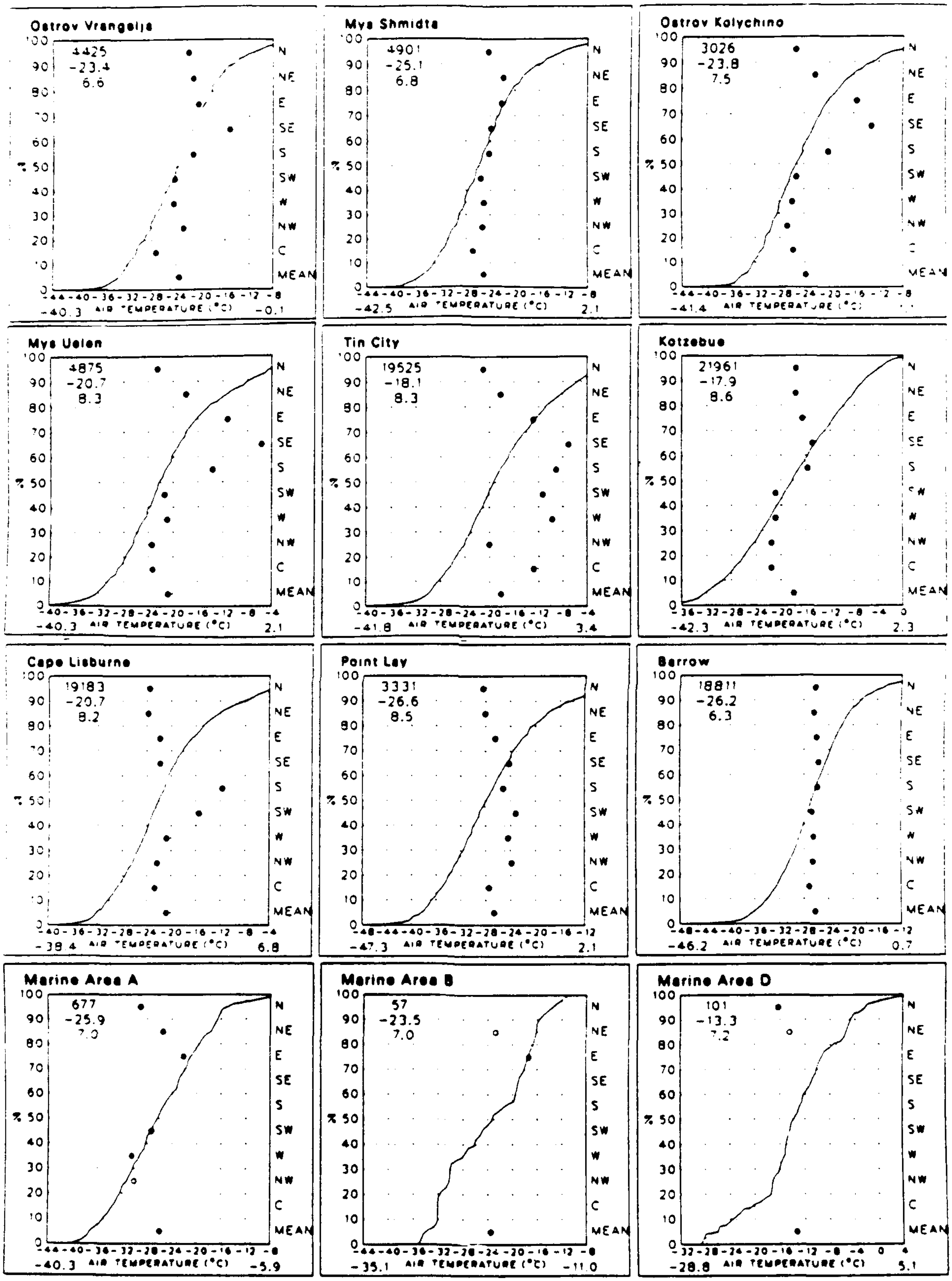


February

After Brower et al. 1988

Figure 22b

Air Temperature/Wind Direction

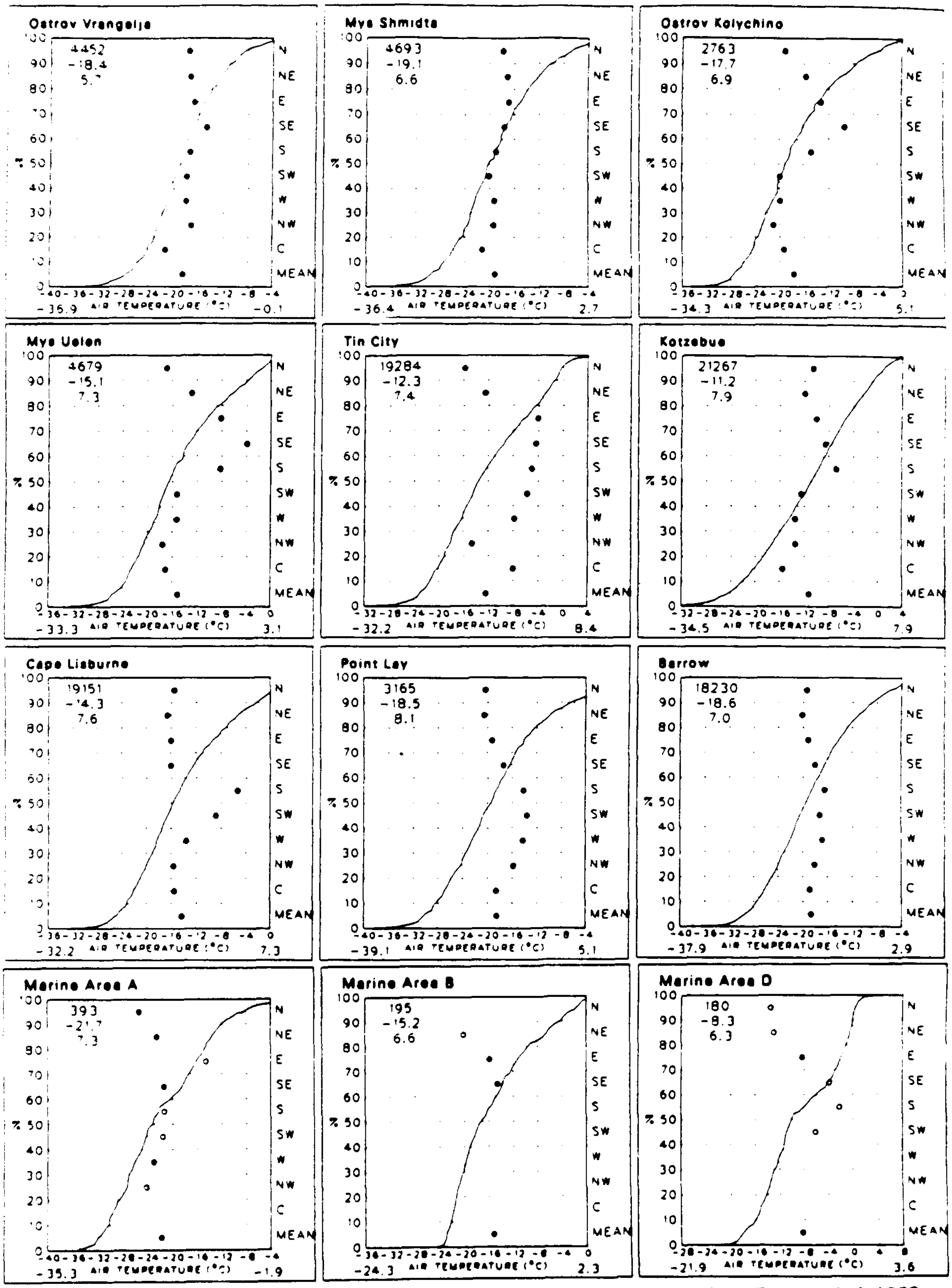


March

After Brower et al. 1988

Figure 22c

Air Temperature/Wind Direction

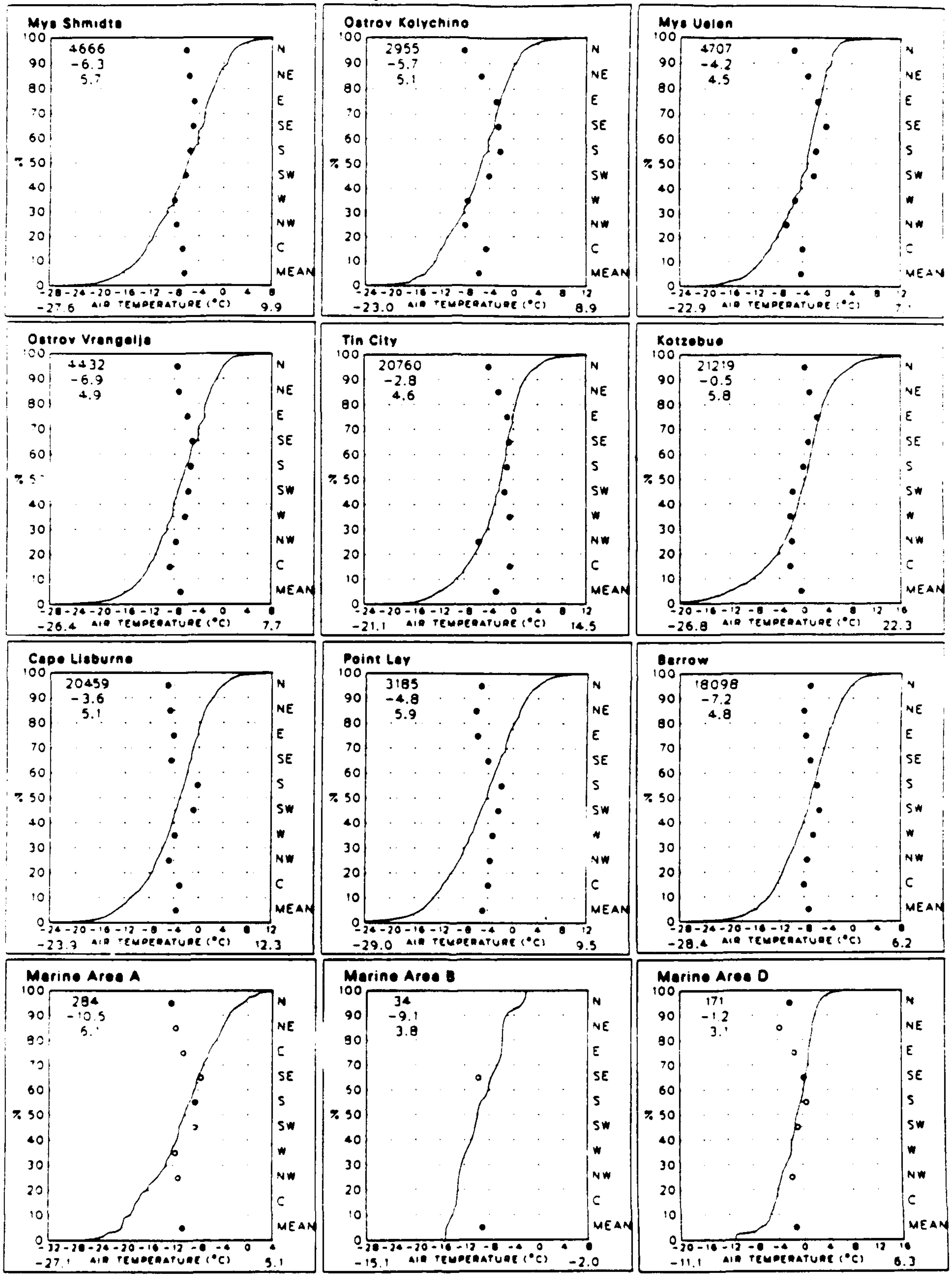


April

After Brower et al. 1988

Figure 22d

Air Temperature/Wind Direction

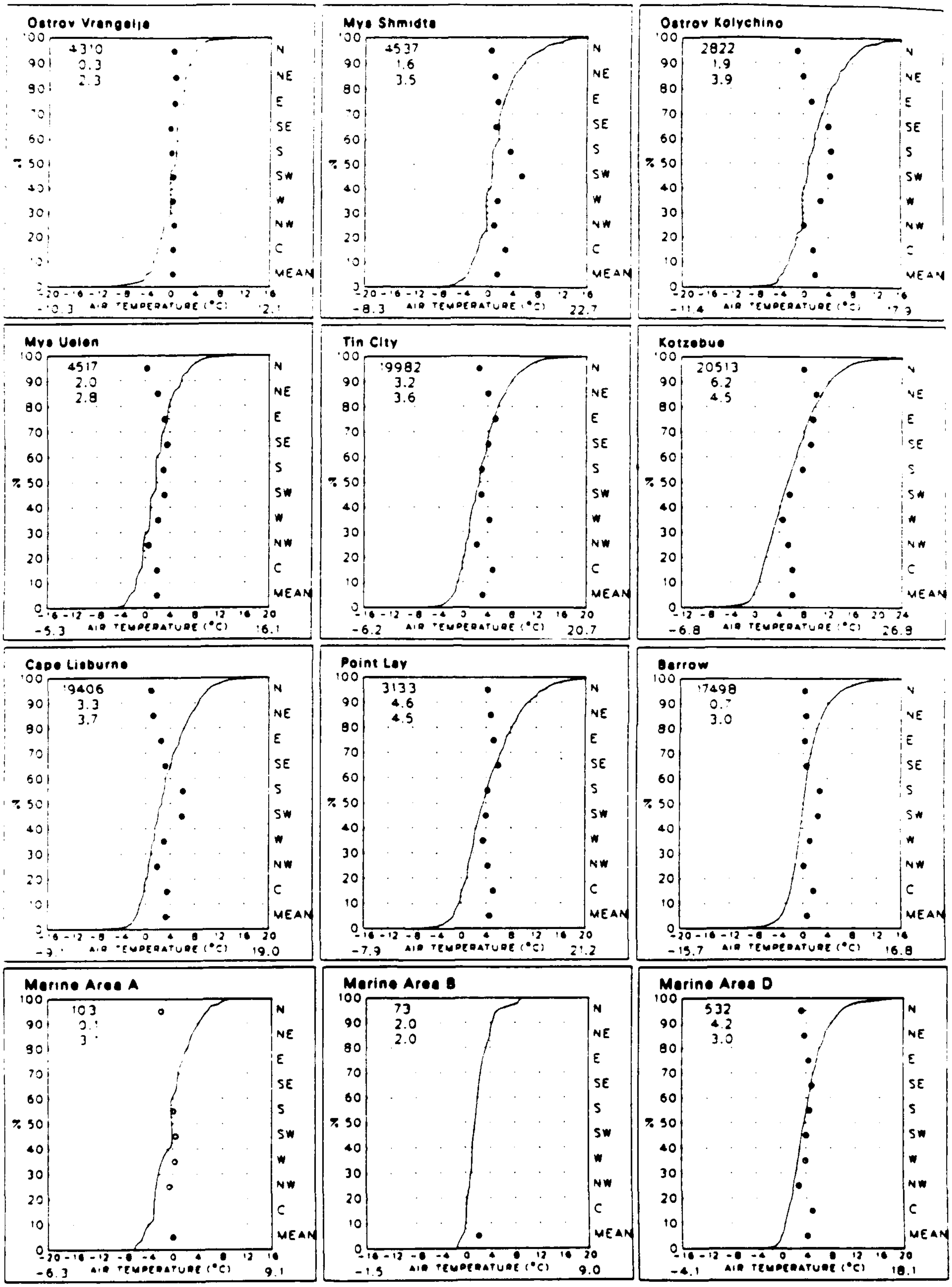


May

After Brower et al. 1988

Figure 22e

Air Temperature/Wind Direction

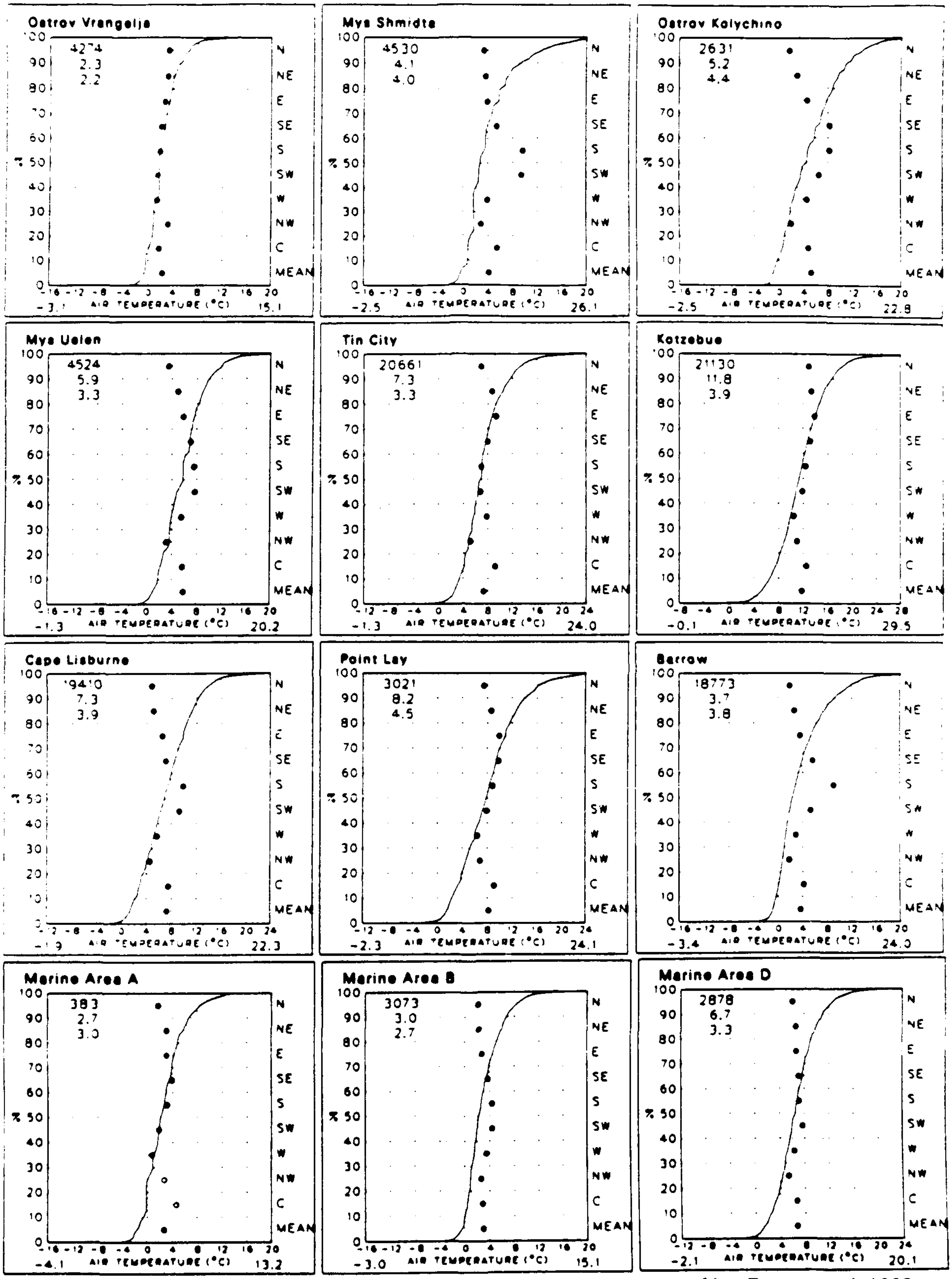


June

After Brower et al. 1988

Figure 22f

Air Temperature/Wind Direction

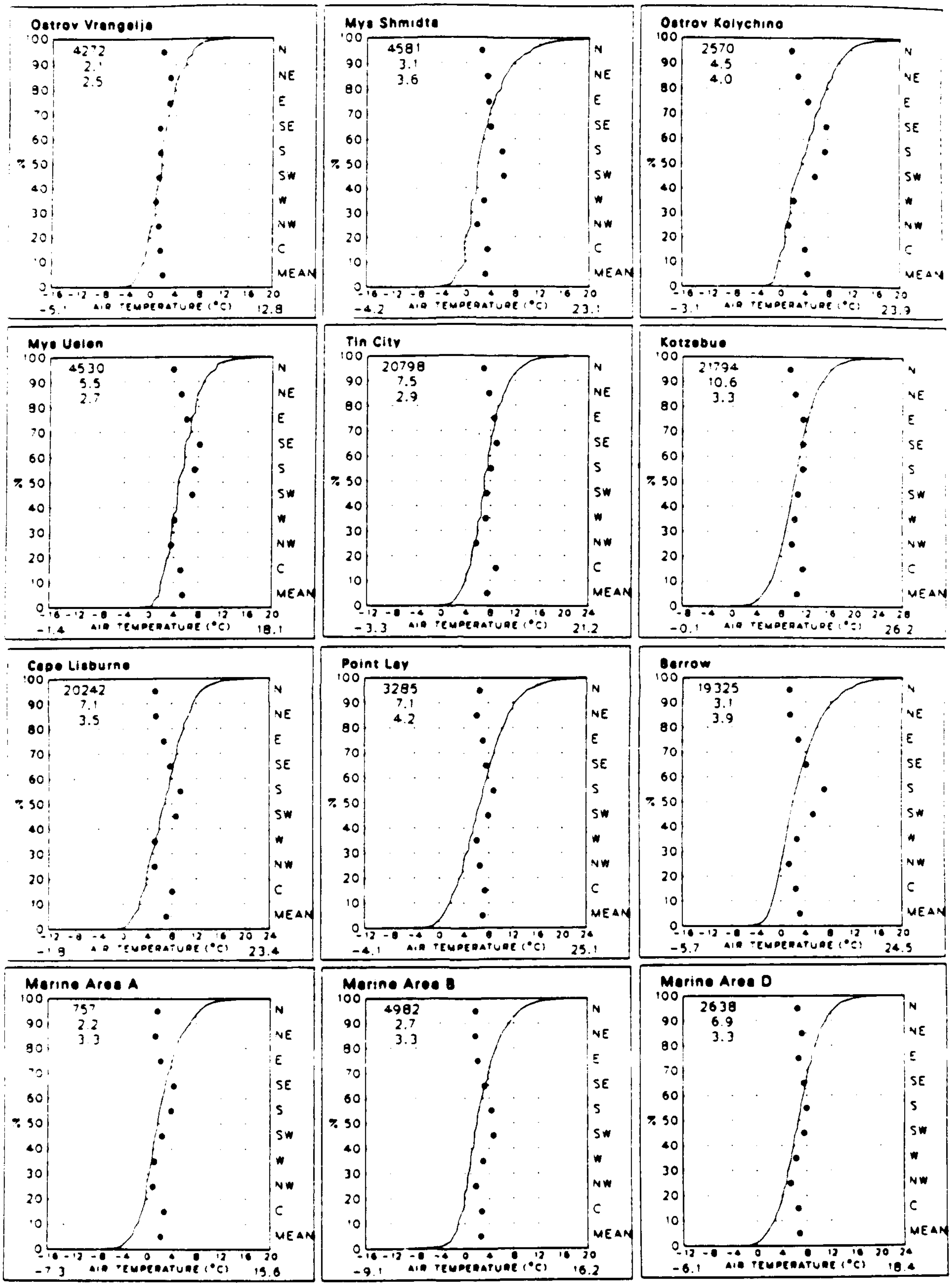


July

After Brower et al. 1988

Figure 22g

Air Temperature/Wind Direction

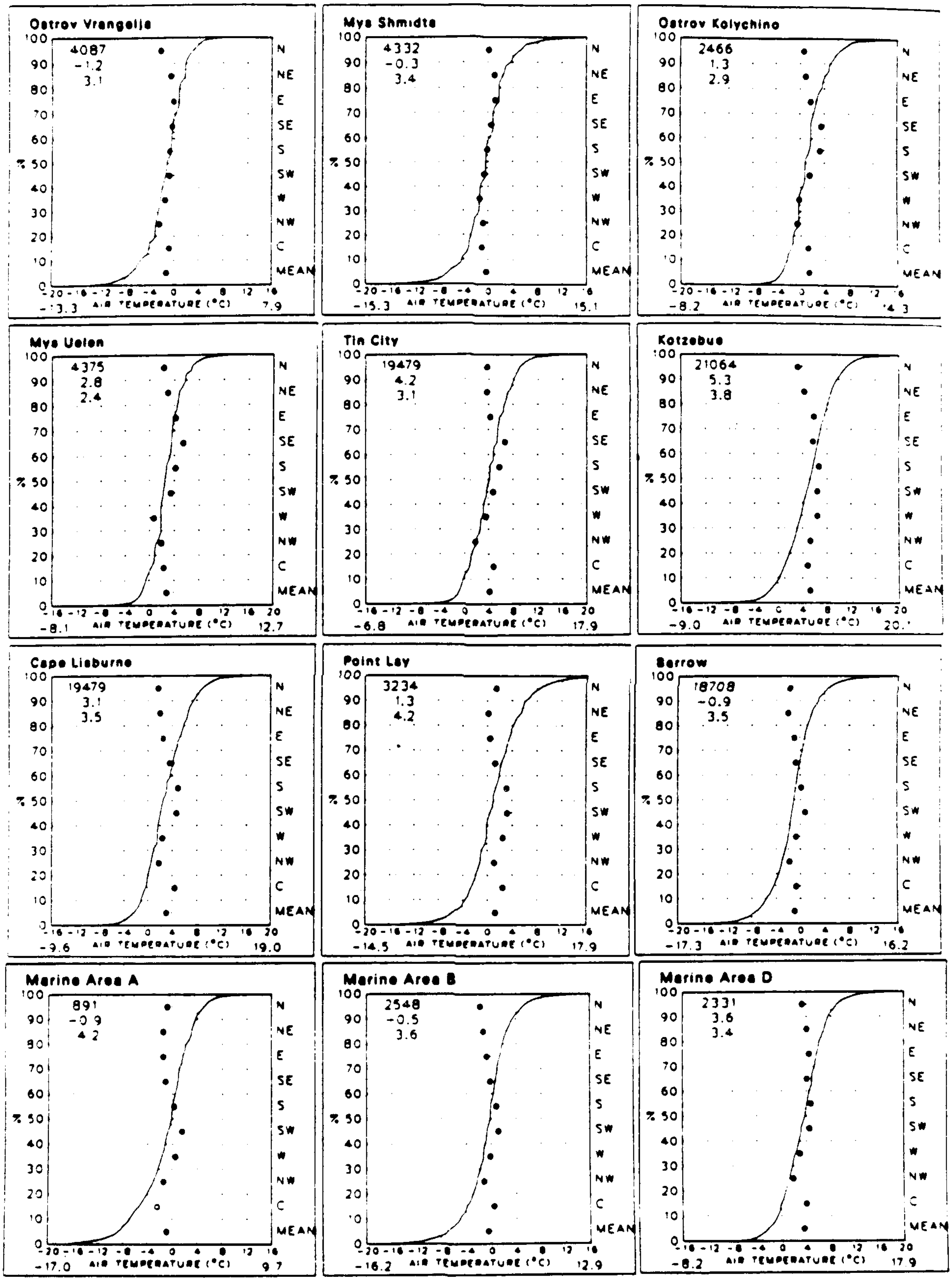


August

After Brower et al. 1988

Figure 22h

Air Temperature/Wind Direction

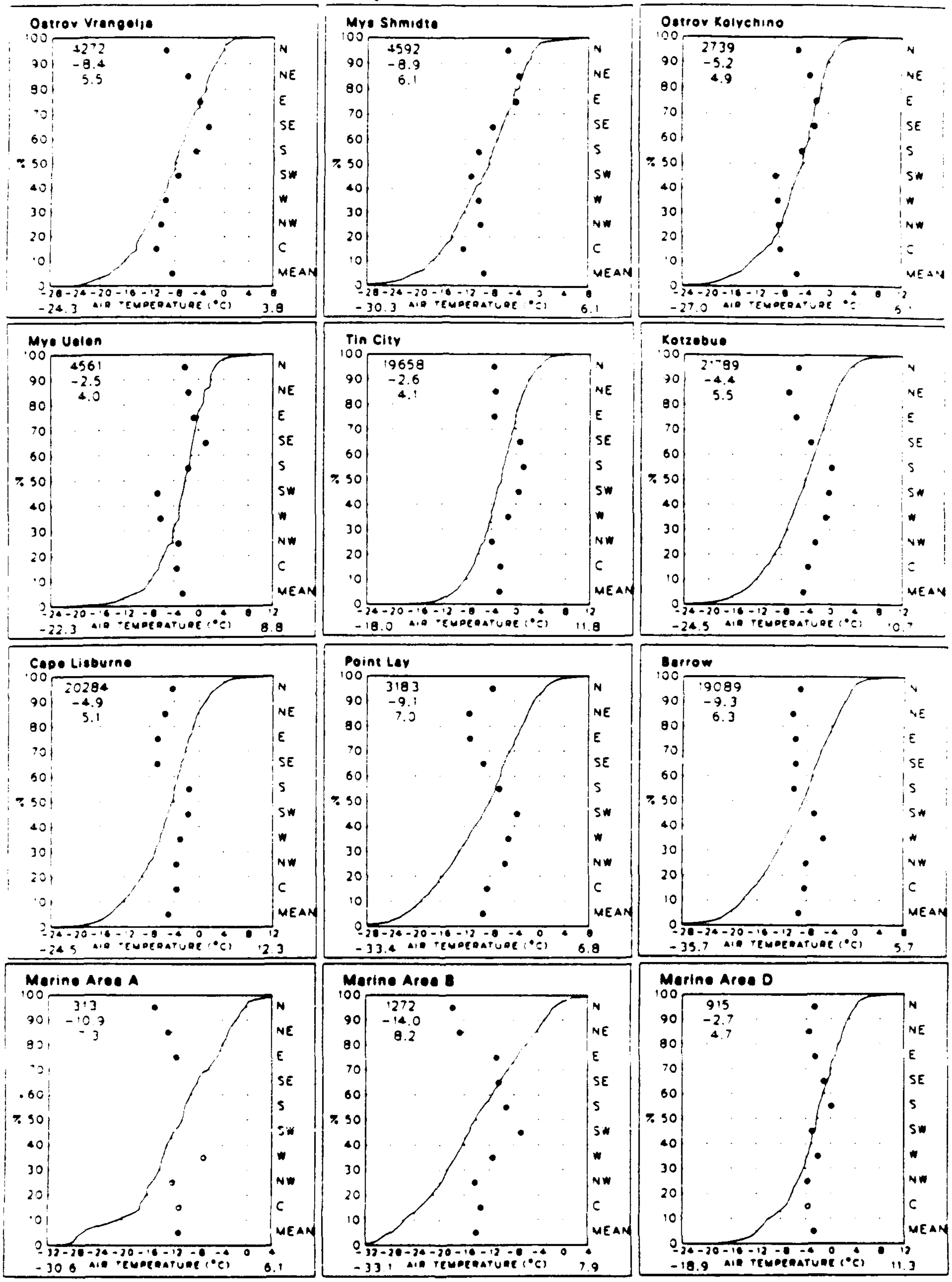


September

After Brower et al. 1988

Figure 22i

Air Temperature/Wind Direction

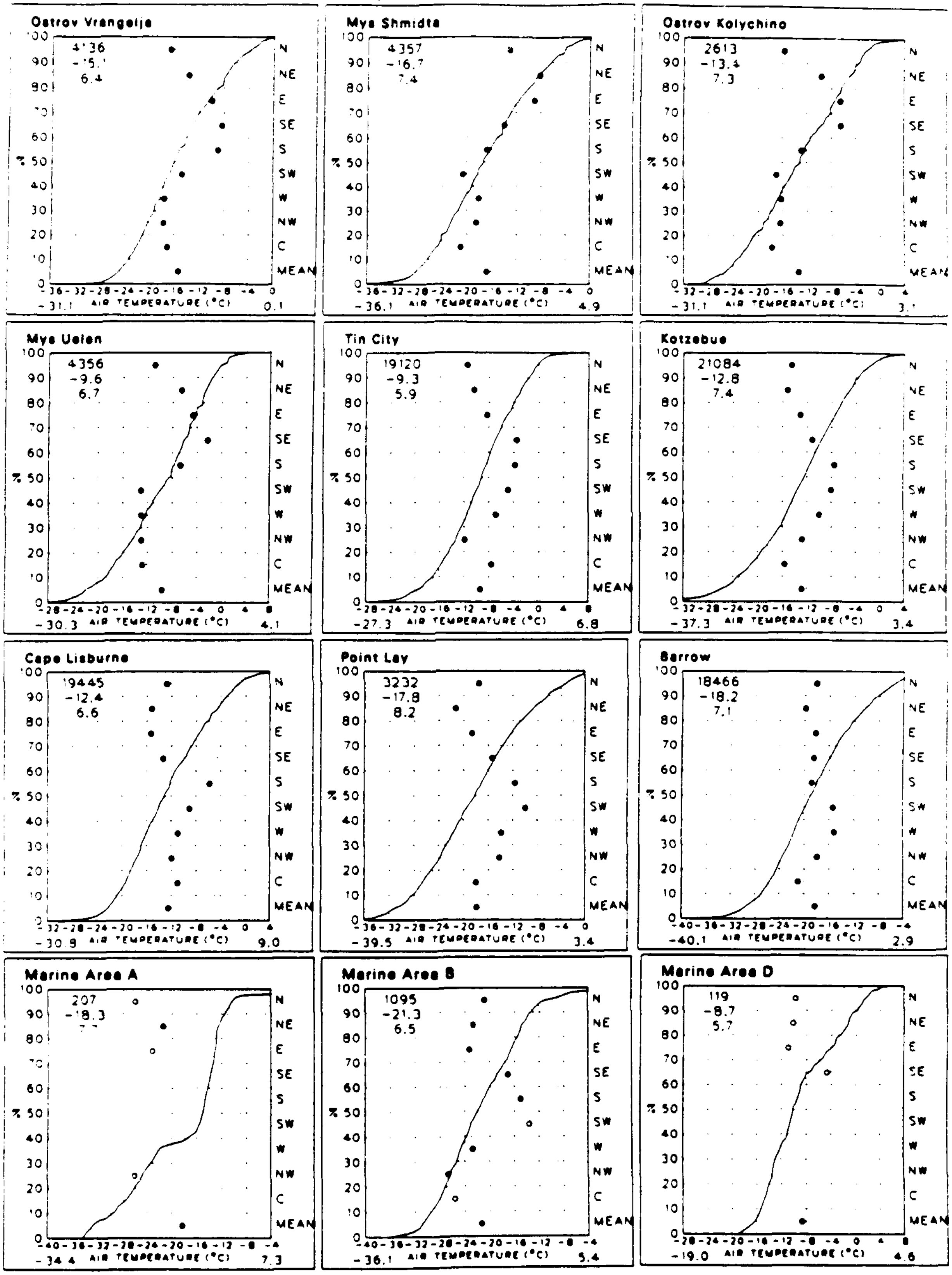


October

After Brower et al. 1988

Figure 22j

Air Temperature/Wind Direction

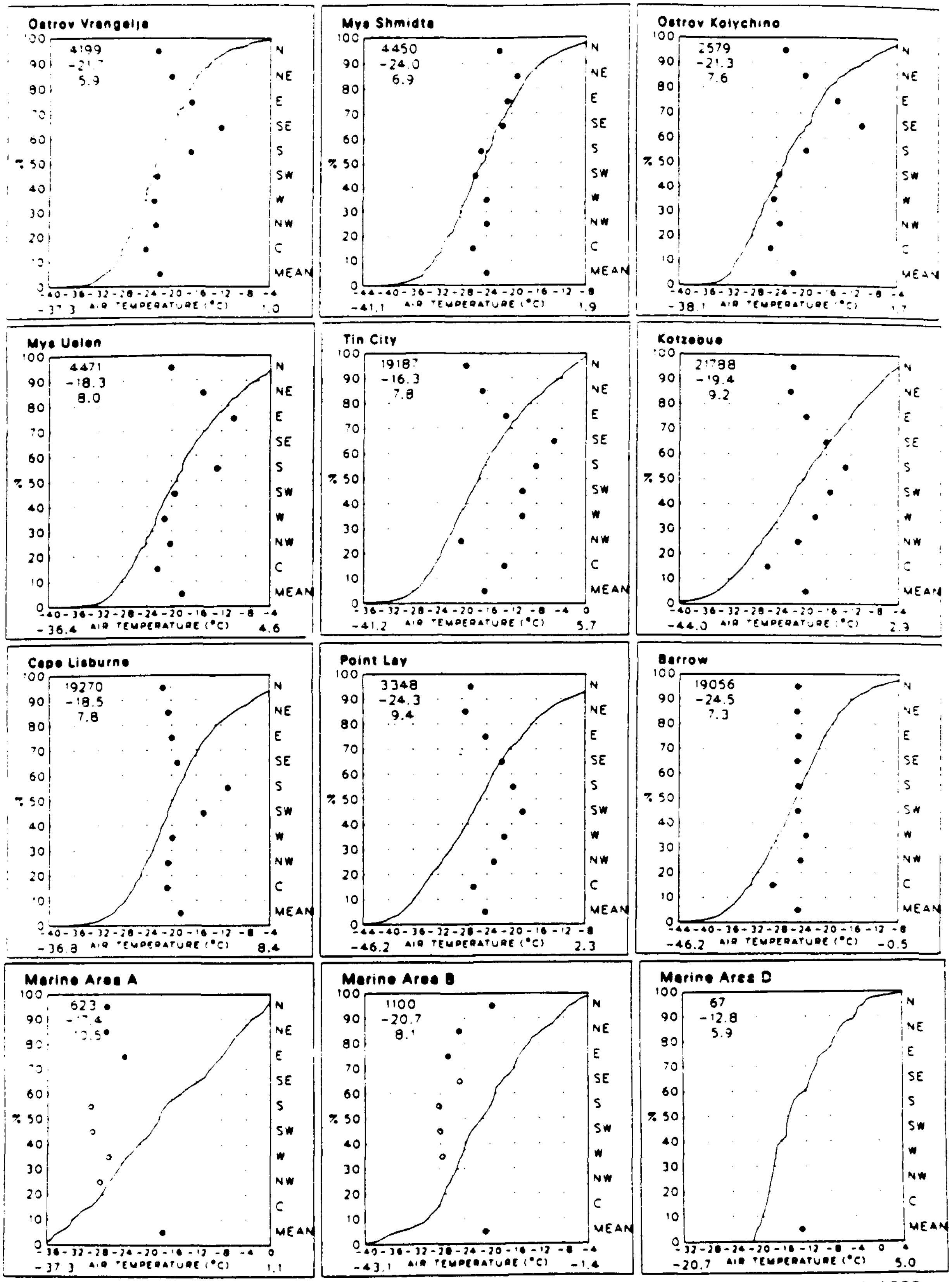


November

After Brower et al. 1988

Figure 22k

Air Temperature/Wind Direction



December

After Brower et al. 1988

Figure 22l

WIND

Average surface Chukchi Sea winds are light, perhaps 8-10 knots. Because of the isolating effect of the surface temperature inversion, the surface layer often avoids the high winds from circulating system above it. High surface winds occur occasionally, usually lasting one to three days, and usually are associated with strong pressure gradients. The locally preferred wind direction is often related to topography. Accurate estimates of wind speed and direction are necessary to establish the likely path or fate of an oil or an oil-ice spill, to anticipate wind-chill for personnel, and to estimate any visibility problems from blowing snow or fog.

Wind and wind related data from nine land stations and accumulated from three marine areas show the extreme seasonal and geographic variability in winds typical of the Chukchi Sea. For instance, the winter Beaufort high drives an easterly wind at Point Barrow, northeasterly winds offshore of Cape Lisburne, and Tin City. Graphs and isopleth maps for wind data are the most practical way to describe this variability. Figure 23 describes the Beaufort Scale/WMO Code; a visual wind equivalent scale.

Figures 24a-24l indicate scalar mean wind speed and wind chill equivalent temperatures less than 30°C.

Figures 25a-25l show the wind speed and wind direction data from nine land stations and three marine areas.

Figures 26a-26l show isopleths of winds under 10 and over 35 knots.

Figures 27a-27l show the isopleths of winds between 11-21 knots and 22-33 knots in percent frequency units.

WIND SPEED IN KNOTS (WMO Code, 1982)

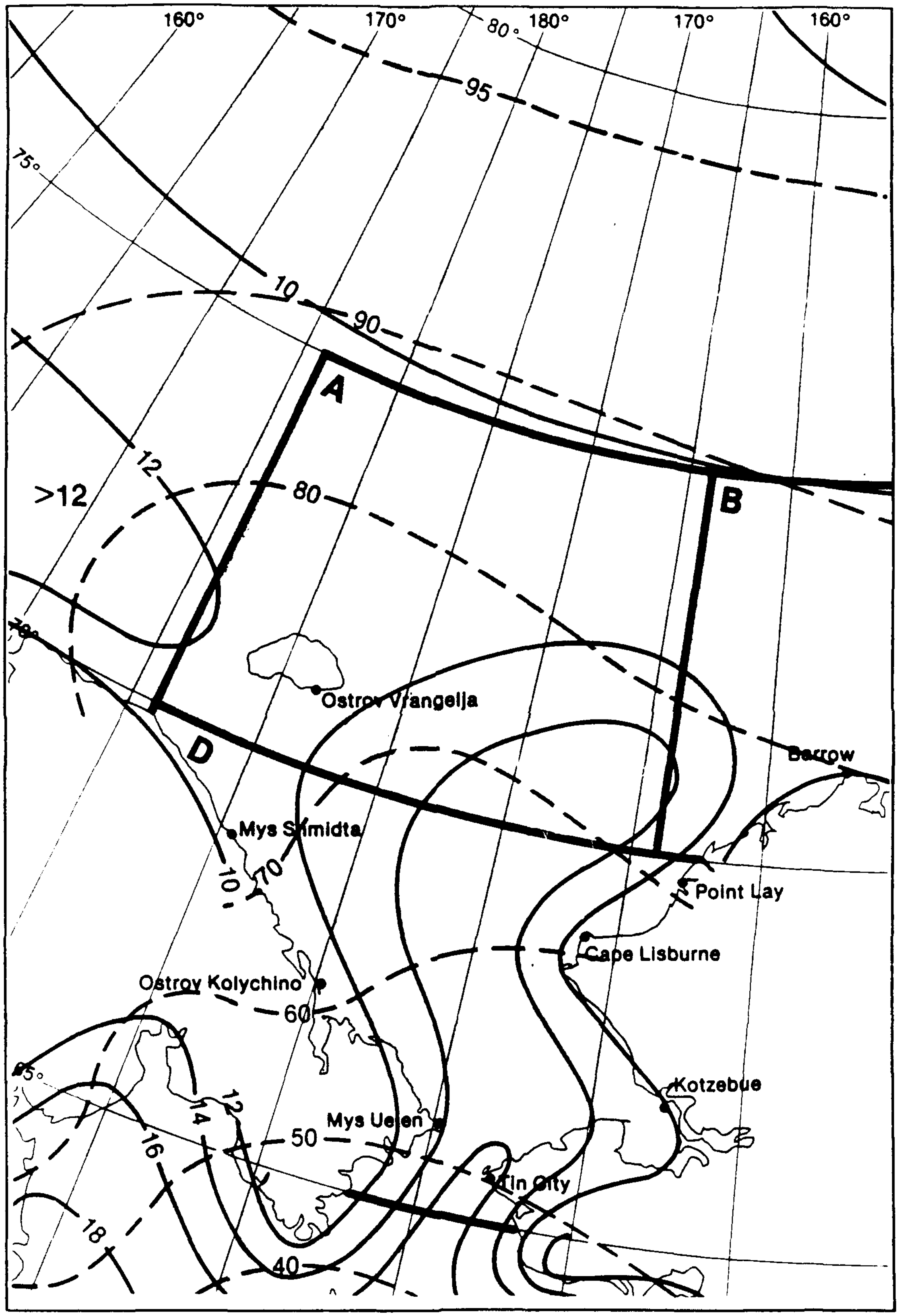
This table is based on sea conditions over deep water with a fully developed sea. There will be frequent cases where the sea will not be fully developed bacause the wind has not blown long enough over a sufficient distance (fetch). Other factors such as currents and water depth will also affect the look of the sea.

Code figs. (Knots)	Beaufort	Description	Sea criterion when sea fully developed	Probable ht. of waves in m (ft) Average		Maximum	
00	0	Calm	Sea like a mirror	-			-
01-03	1	Light air	Ripples with the appearance of scales are formed, but without foam crests	0.1	(¼)	0.1	(¼)
04-06	2	Light breeze	Small wavelets, still short but more pronounced, crests have a glassy appearance and do not break	0.2	(½)	0.3	(1)
07-10	3	Gentle breeze	Large wavelets; crests begin to break; foam of glassy appearance; perhaps scattered white horses	0.6	(2)	1	(3)
11-16	4	Moderate breeze	Small waves, becoming longer; fairly frequent white horses	1	(3½)	1.5	(5)
17-21	5	Fresh breeze	Moderate waves, taking a more pronounced long form; many white horses are formed (chance of some spray)	2	(6)	2.5	(8½)
22-27	6	Strong breeze	Large waves begin to form; white foam crests are more extensive everywhere (probably some spray)	3	(9½)	4	(13)
28-33	7	Near gale	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind	4	(13½)	5.5	(19)
34-40	8	Gale	Moderately high waves of greater length; edges of crests begin to break into the spindrift; the foam is blown in well-marked streaks along the direction of the wind	5.5	(18)	7.5	(25)
41-47	9	Strong gale	High waves; dense streaks of foam along the direction of the wind; crests of waves begin to topple, tumble and roll over; spray may affect visibility	7	(23)	10	(32)
48-55	10	Storm	Very high waves with long overhanging crests; the resulting foam, in great patches, is blown in dense white streaks along the direction of the wind; on the whole, the surface of the sea takes on a white appearance; tumbling of the sea becomes heavy and shock-like; visibility affected	9	(29)	12.5	(41)
56-63	11	Violent Storm	Exceptionally high waves (small and medium-sized ships might be for a time lost to view behind the waves); the sea is completely covered with long white patches of foam lying along the direction of the wind; everywhere the edges of the wave crests are blown into froth; visibility affected	11.5	(37)	16	(52)
64 and over	12	Hurricane	The air is filled with foam and spray; sea completely white with driving spray; visibility very seriously affected	14	(45)	-	XX

Note: For winds over 99 knots, add 50 to dd (direction) and enter the tens and units digits of the wind speed for ff; e.g. for a wind from 100° true at 125 knots, dd = 60, and ff = 25.

Figure 23

Mean Wind Speed/Wind Chill ≤ - 30°c



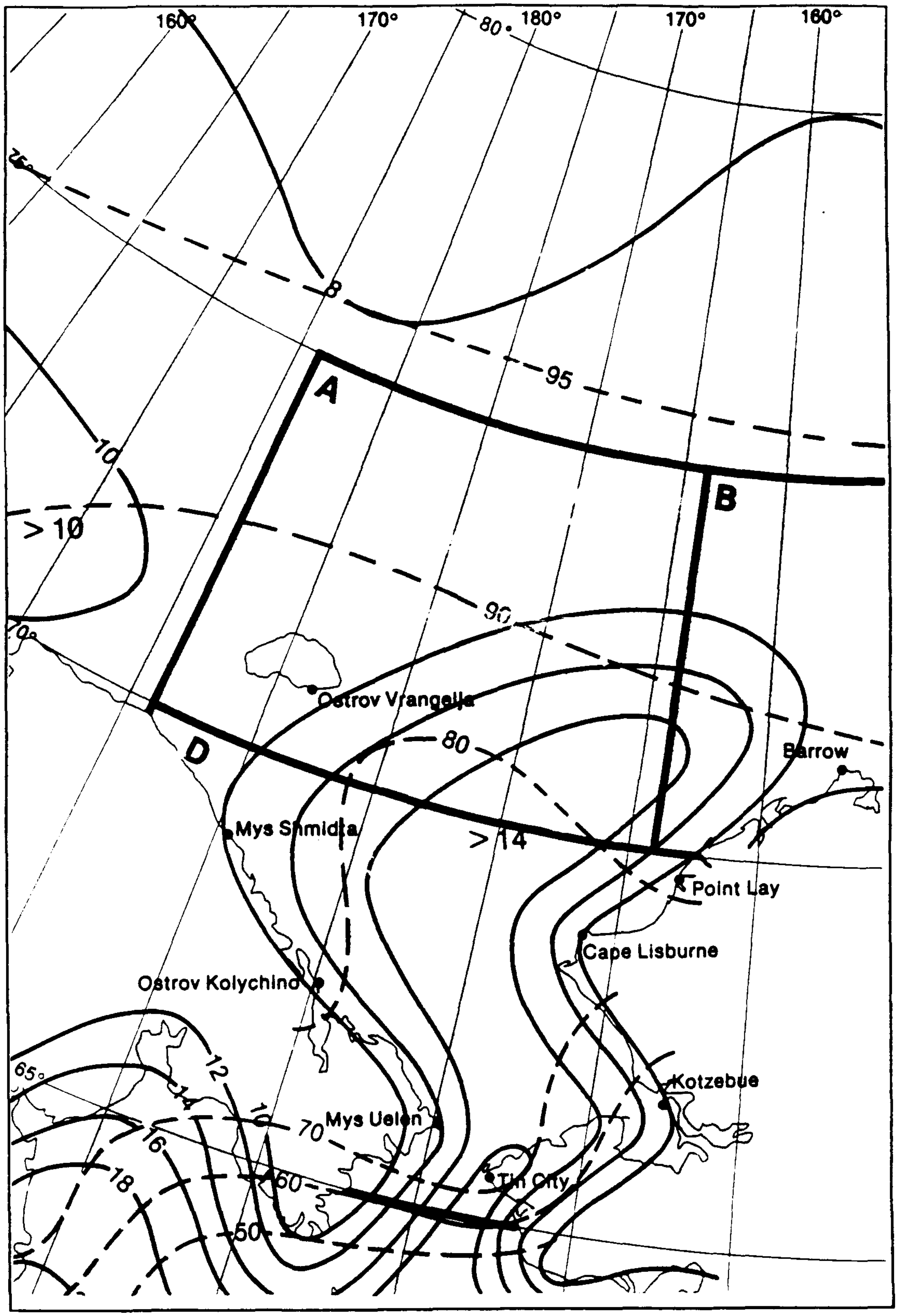
January

After Brower et al. 1988

Legend
- - - %Frequency of Wind Chill ≤-30°C
—— Mean Wind

Figure 24a

Mean Wind Speed/Wind Chill ≤ - 30°c



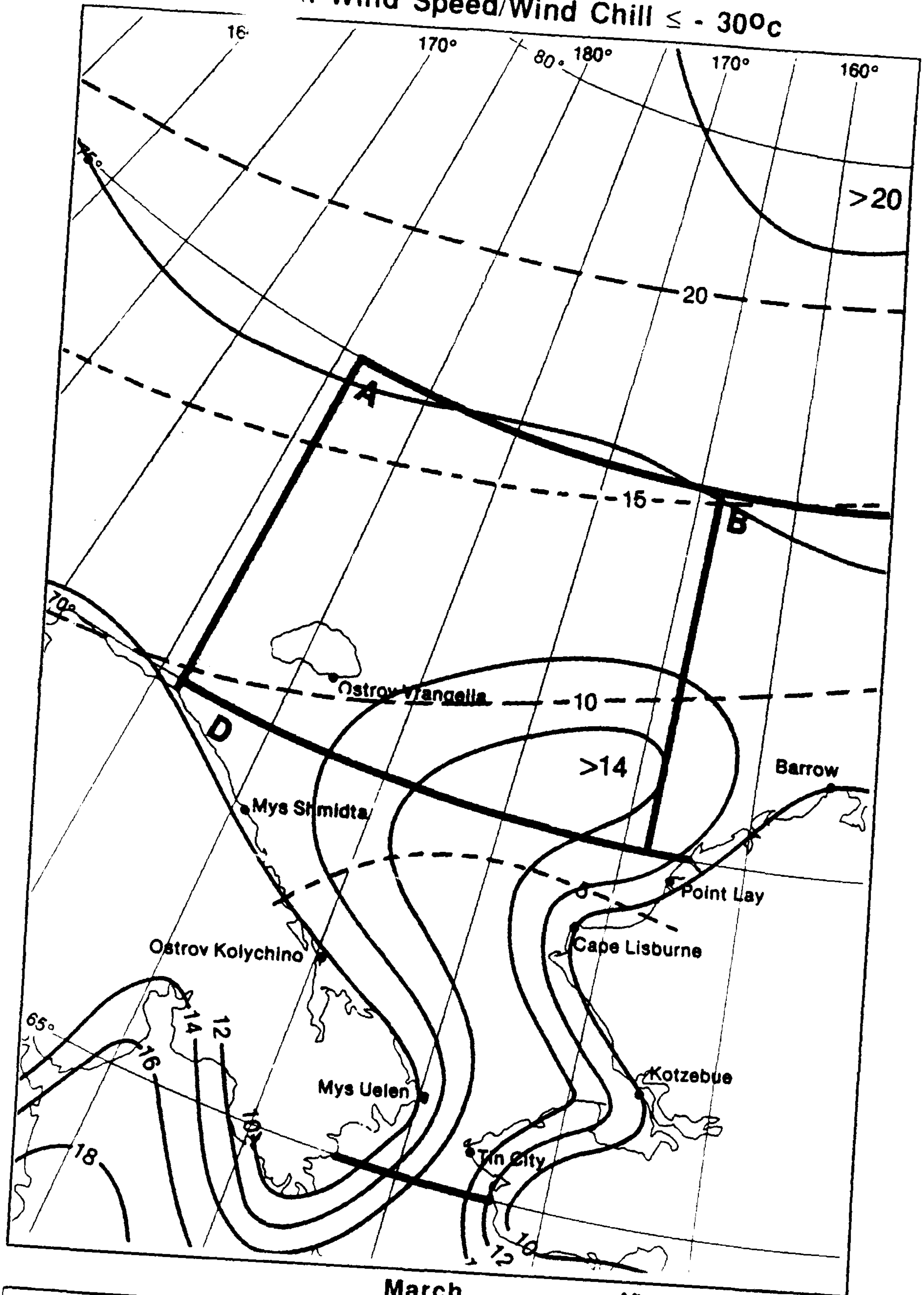
February

After Brower et al. 1988

Legend
- - - - %Frequency of Wind Chill ≤-30°C
——— Mean Wind

Figure 24b

ı Wind Speed/Wind Chill ≤ - 30°c



March

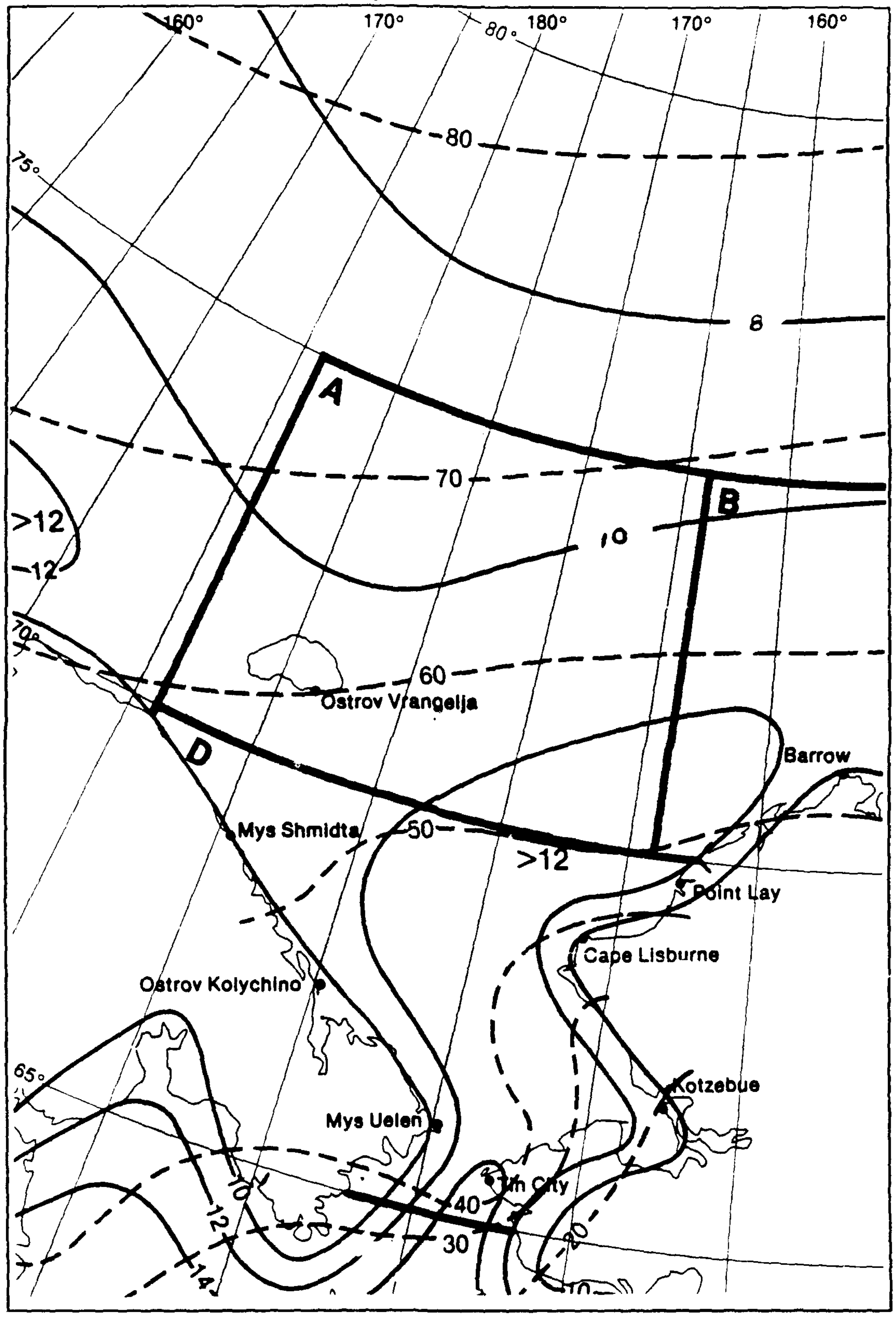
After Brower et al. 1988

Legend

- - - - %Frequency of Wind Chill ≤-30°C
—— Mean Wind

Figure 24c

Mean Wind Speed/Wind Chill ≤ - 30°c



April

After Brower et al. 1988

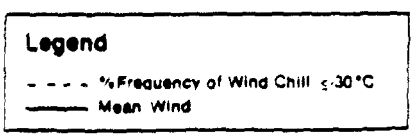
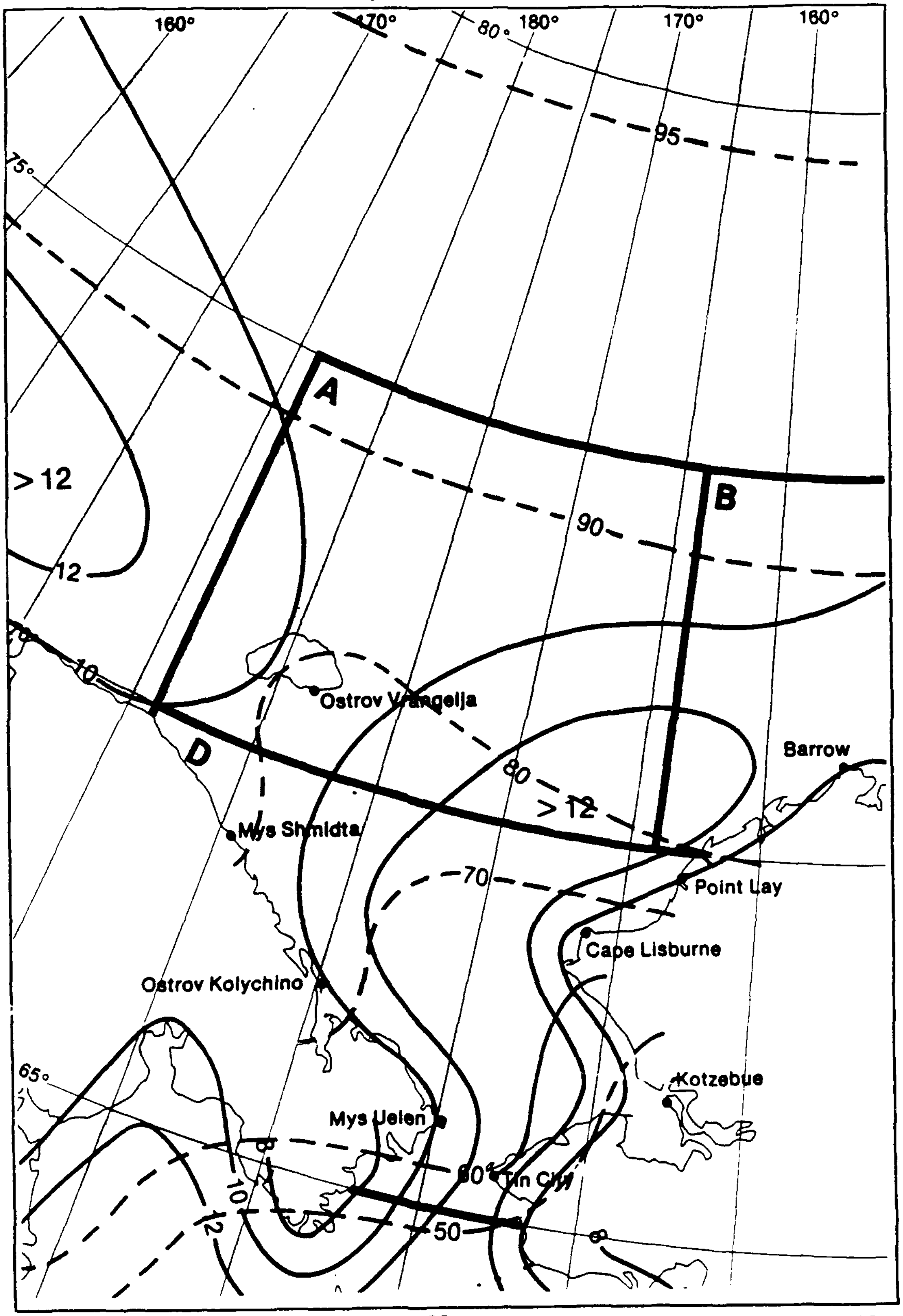


Figure 24d

Mean Wind Speed/Wind Chill ≤ - 30°c



May

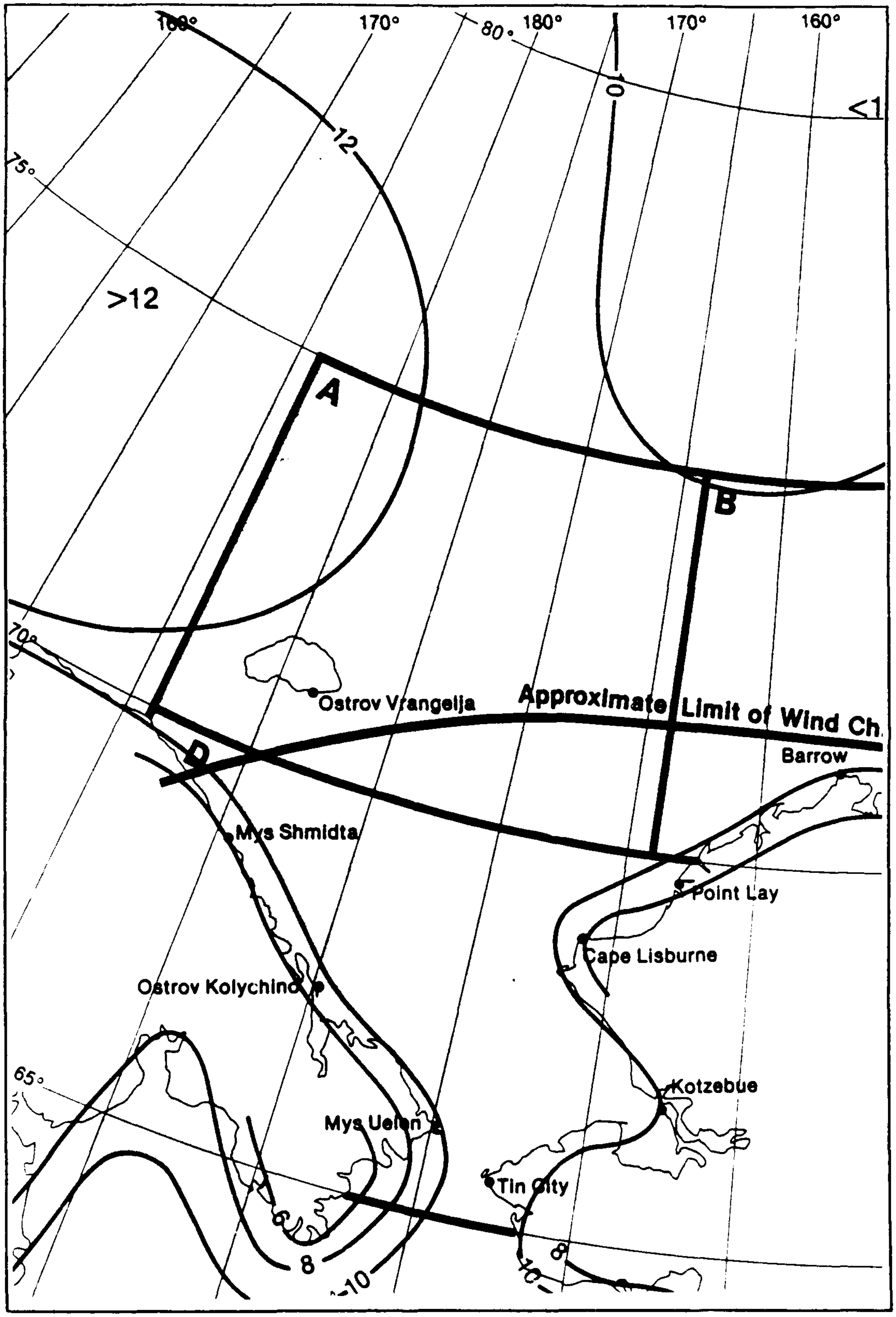
After Brower et al. 1988

Legend

- - - - %Frequency of Wind Chill ≤-30°C
—— Mean Wind

Figure 24e

Mean Wind Speed/Wind Chill ≤ - 30°c



June

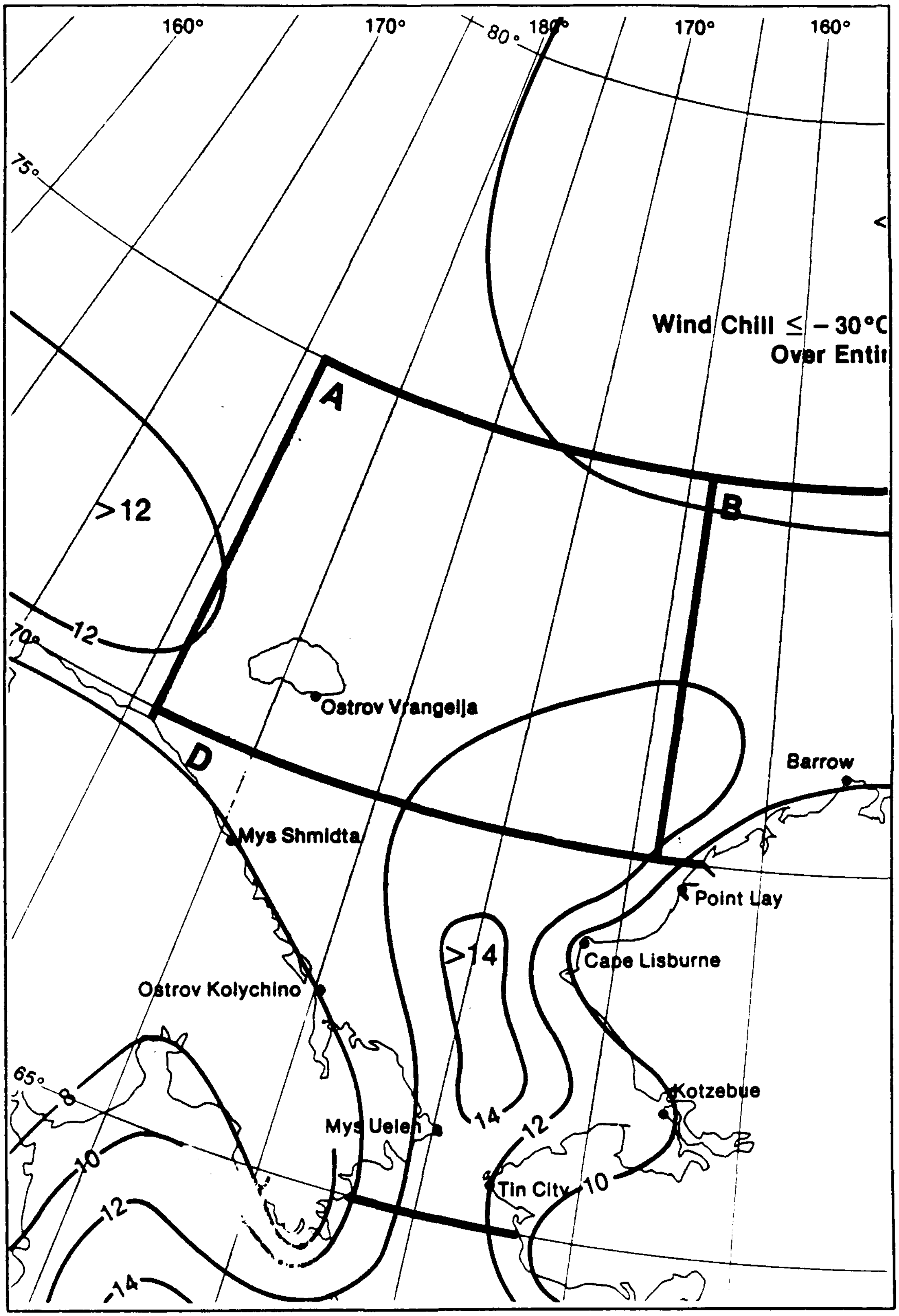
After Brower et al. 1988

Legend

- - - - %Frequency of Wind Chill ≤-30°C
—— Mean Wind

Figure 24f

Mean Wind Speed/Wind Chill ≤ - 30°c



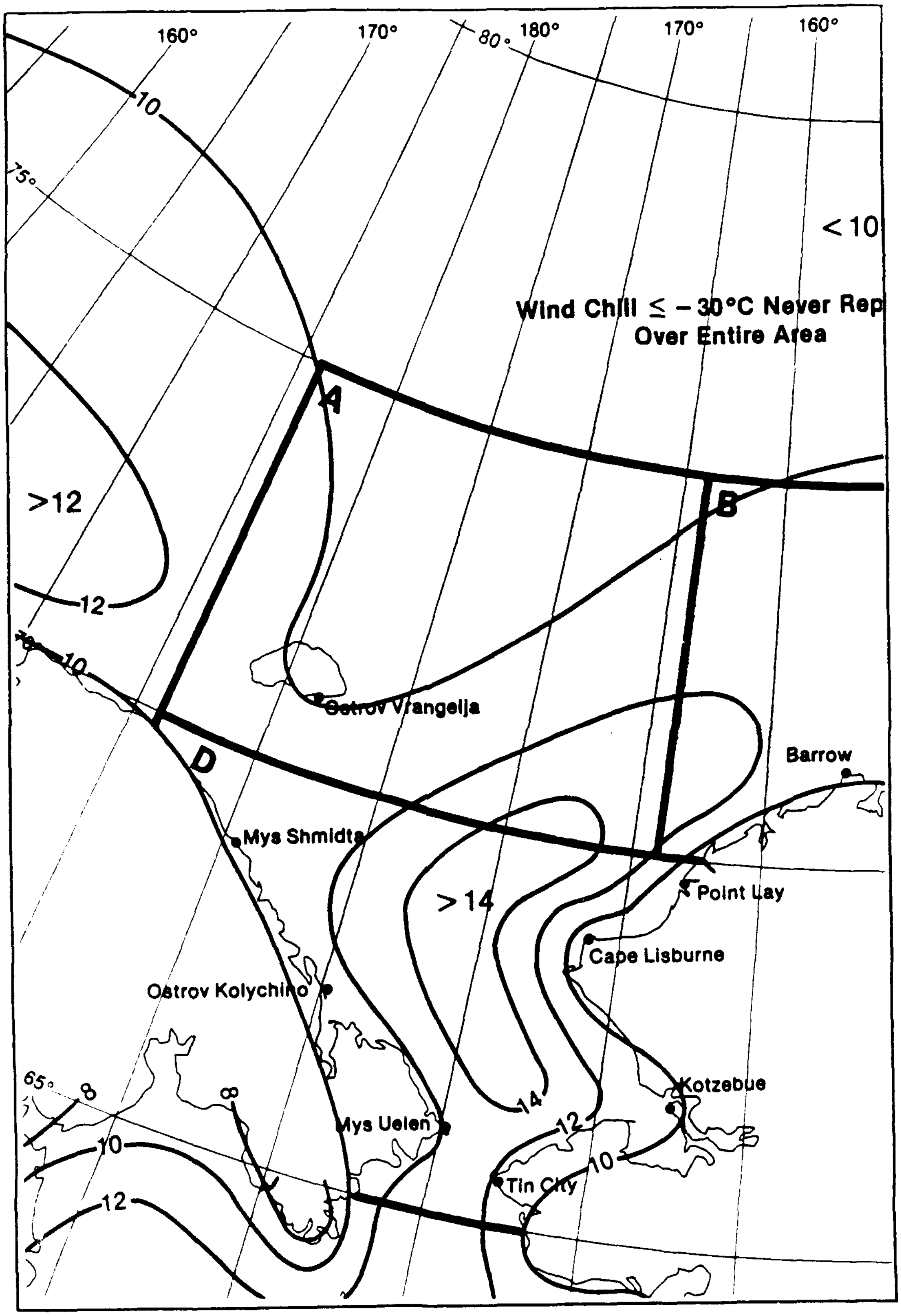
July

After Brower et al. 1988

Legend
- - - - %Frequency of Wind Chill ≤-30°C
——— Mean Wind

Figure 24g

Mean Wind Speed/Wind Chill ≤ - 30°c



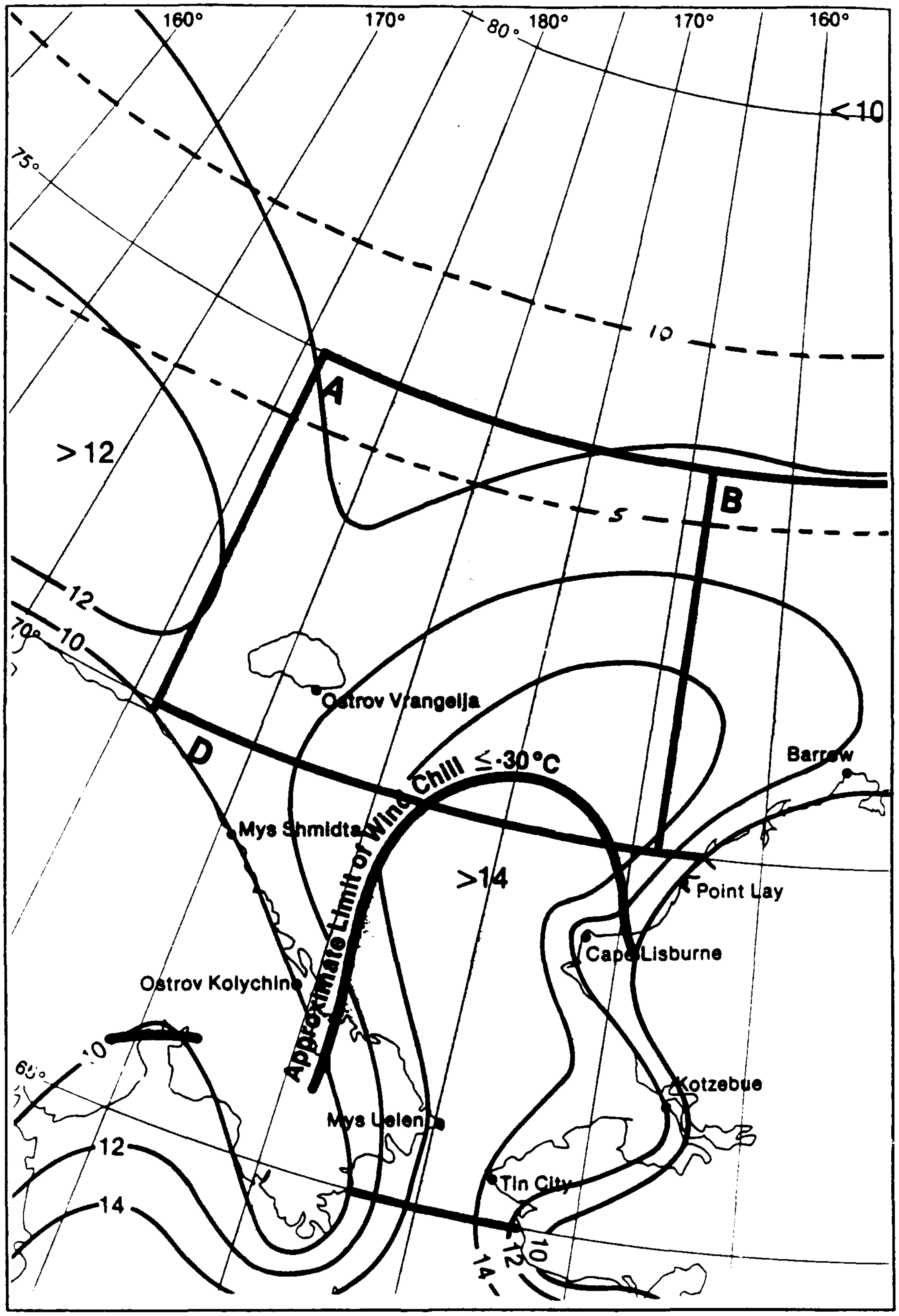
August

After Brower et al. 1988

Legend
- - - - % Frequency of Wind Chill ≤ -30°C
——— Mean Wind

Figure 24h

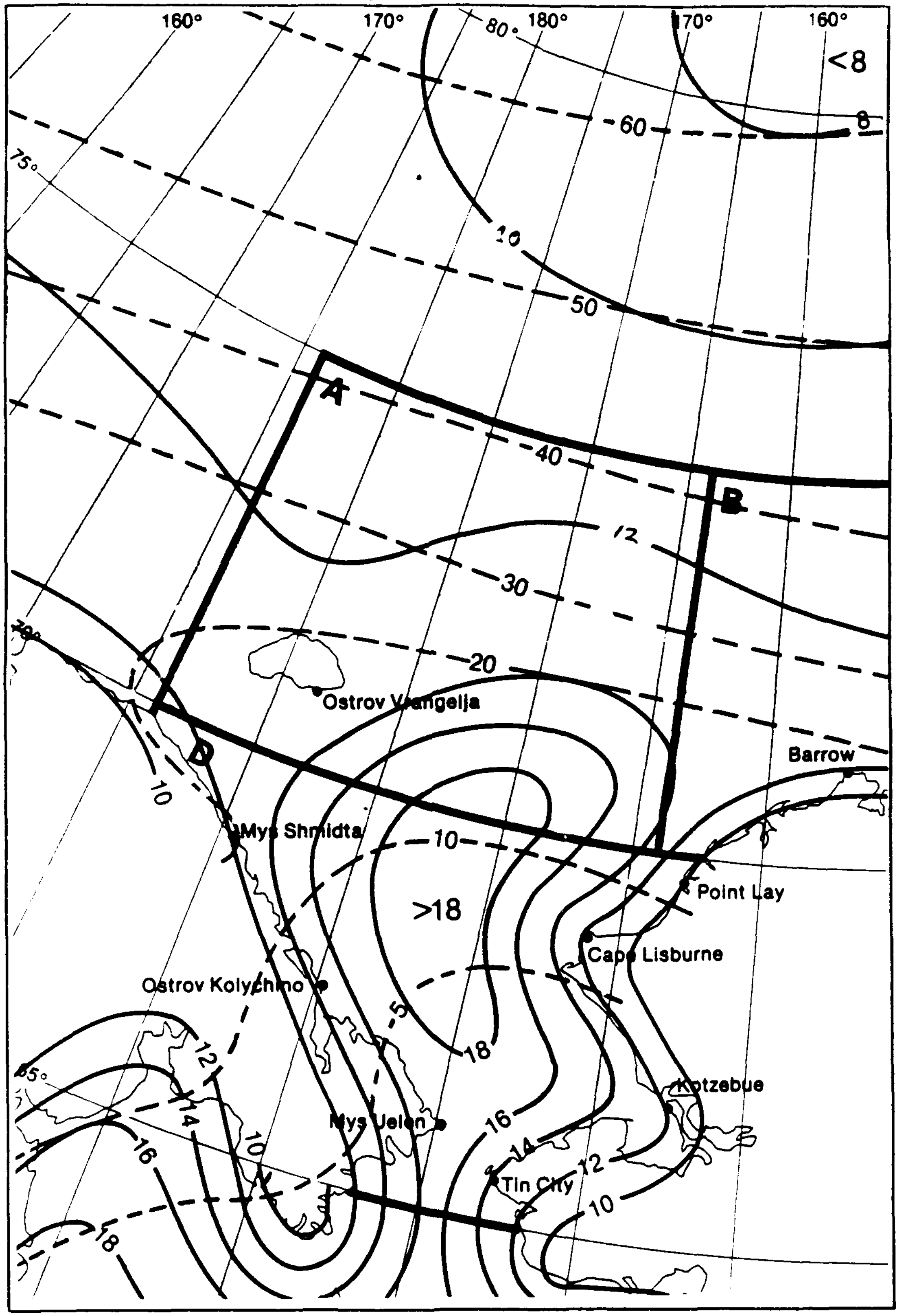
Mean Wind Speed/Wind Chill ≤ - 30°c



Legend
- - - - %Frequency of Wind Chill ≤-30°C
——— Mean Wind

Figure 24i

Mean Wind Speed/Wind Chill ≤ - 30°c



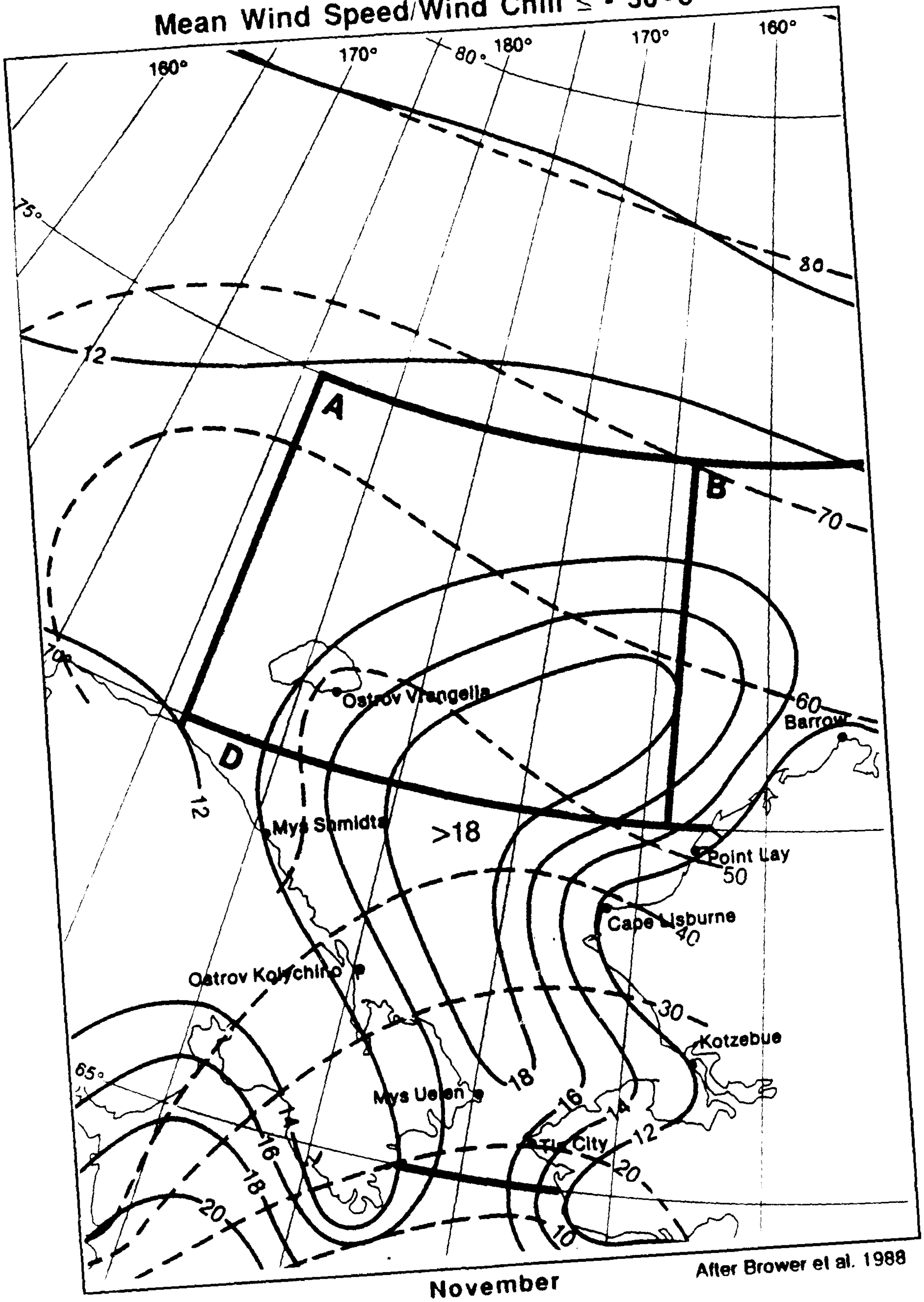
October

After Brower et al. 1988

Legend
- - - - %Frequency of Wind Chill ≤-30°C
——— Mean Wind

Figure 24j

Mean Wind Speed/Wind Chill ≤ - 30°c



After Brower et al. 1988

November

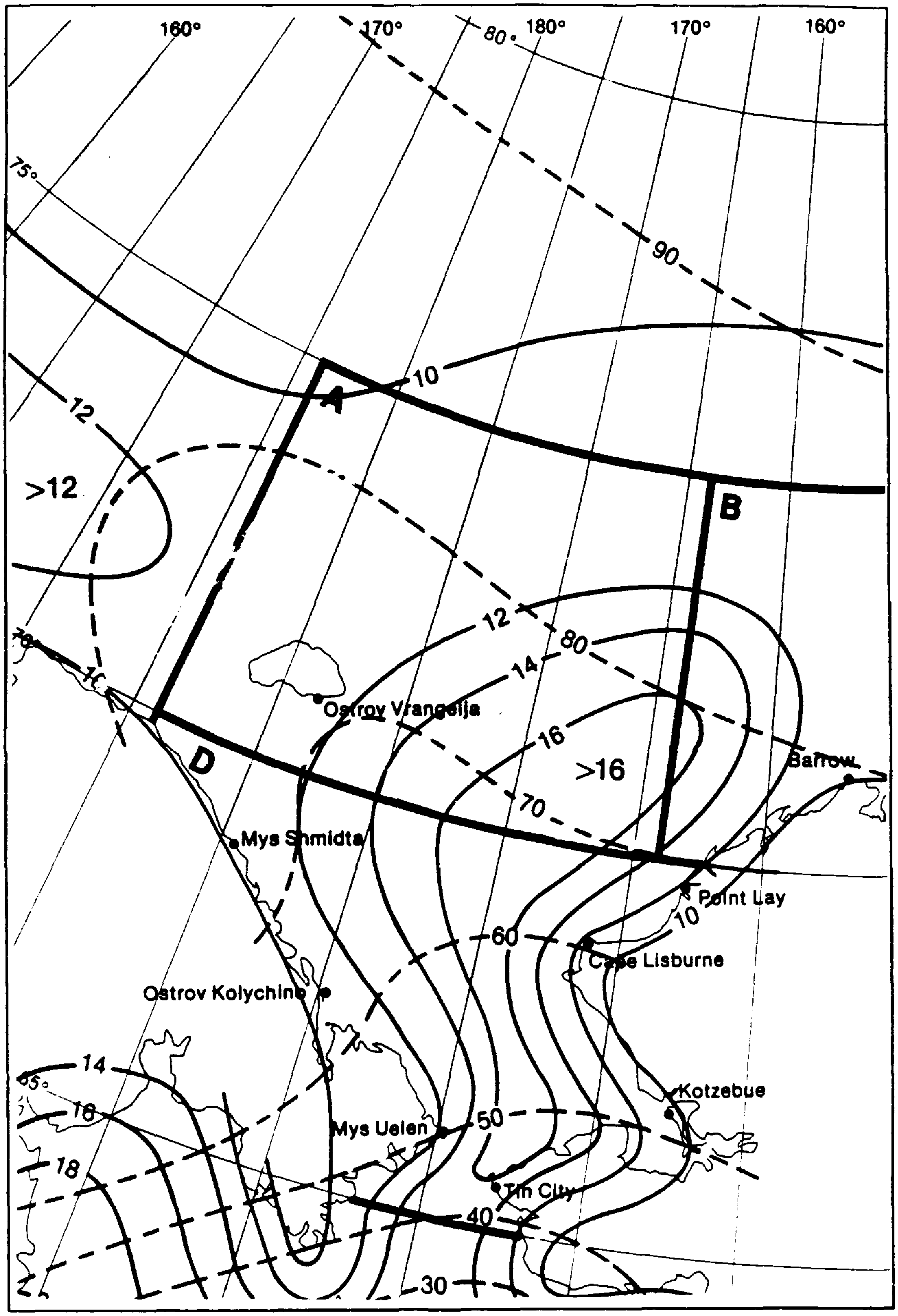
Legend

- - - - % Frequency of Wind Chill ≤ -30°C

——— Mean Wind

Figure 24k

Mean Wind Speed/Wind Chill ≤ - 30°c



December

After Brower et al. 1988

Legend

- - - - %Frequency of Wind Chill ≤-30°C

——— Mean Wind

Figure 24l

Graphs: Wind speed/direction

Direction frequency (top scale): Bars represent percent frequency of winds observed from each direction. Speed frequency (bottom scale): Printed figures represent percent frequency of wind speeds observed from each direction.

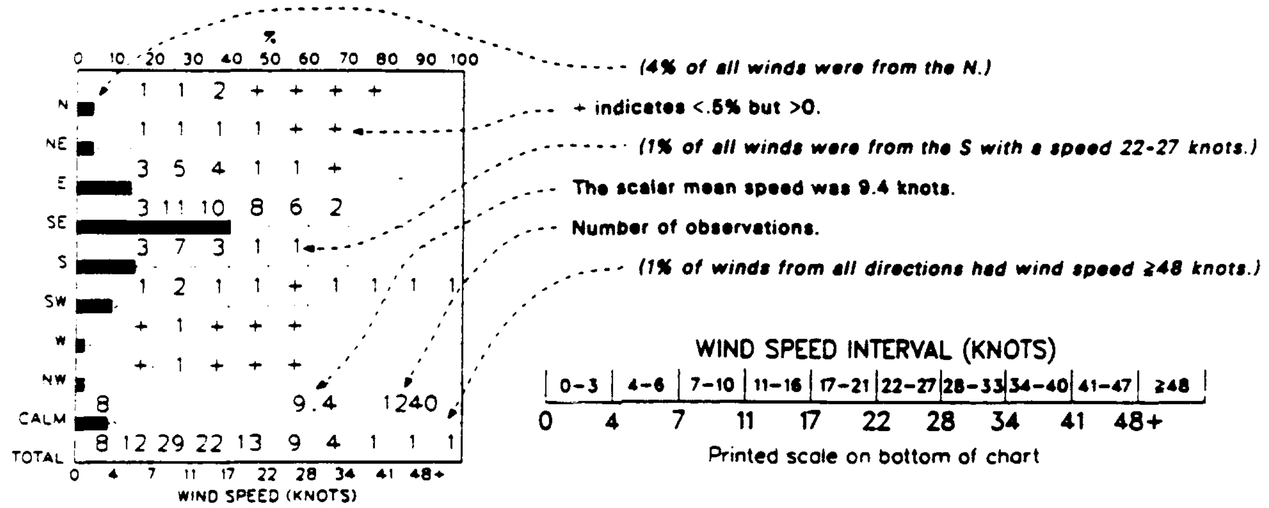
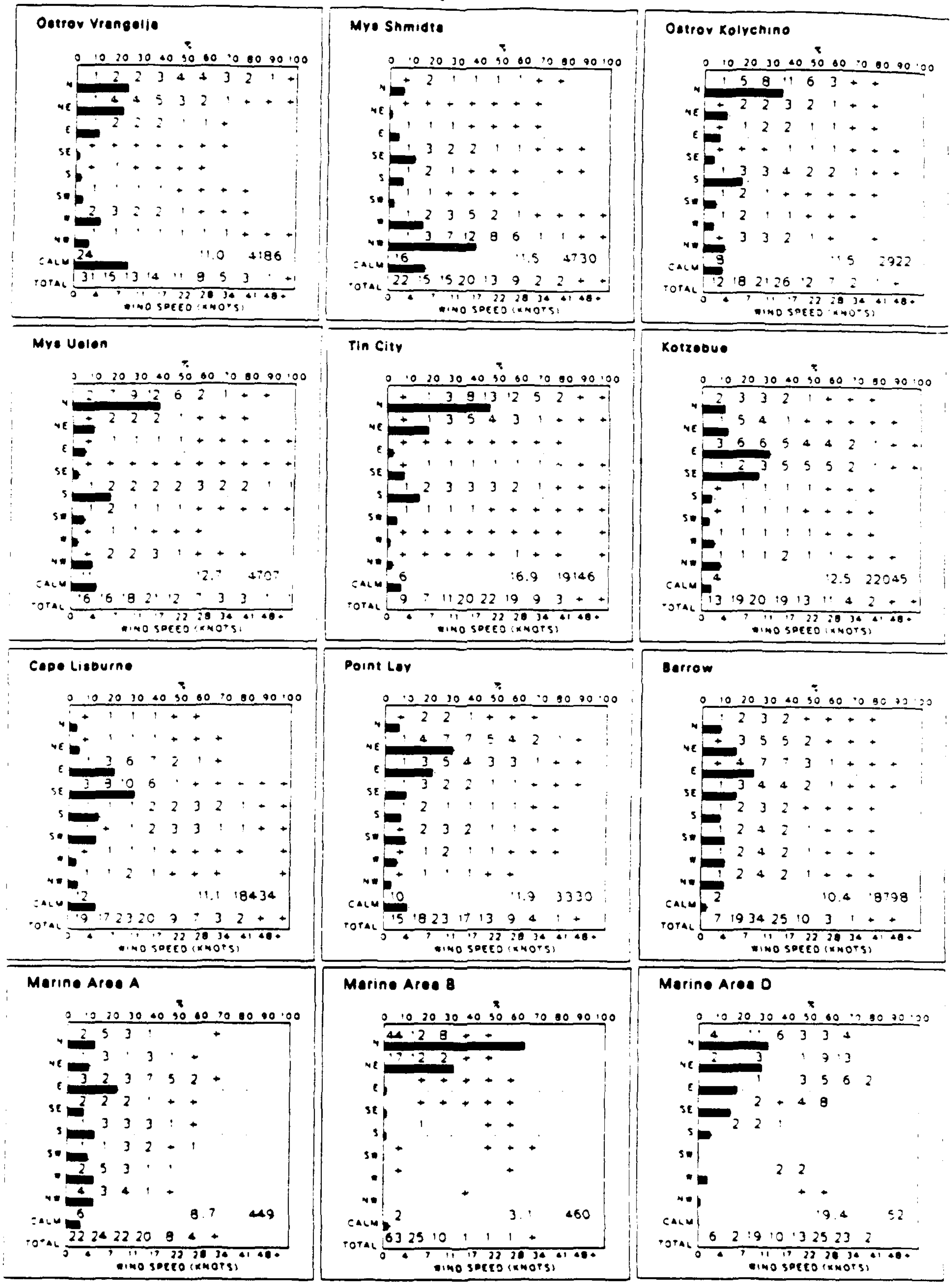


Figure 25

Wind Speed/Direction

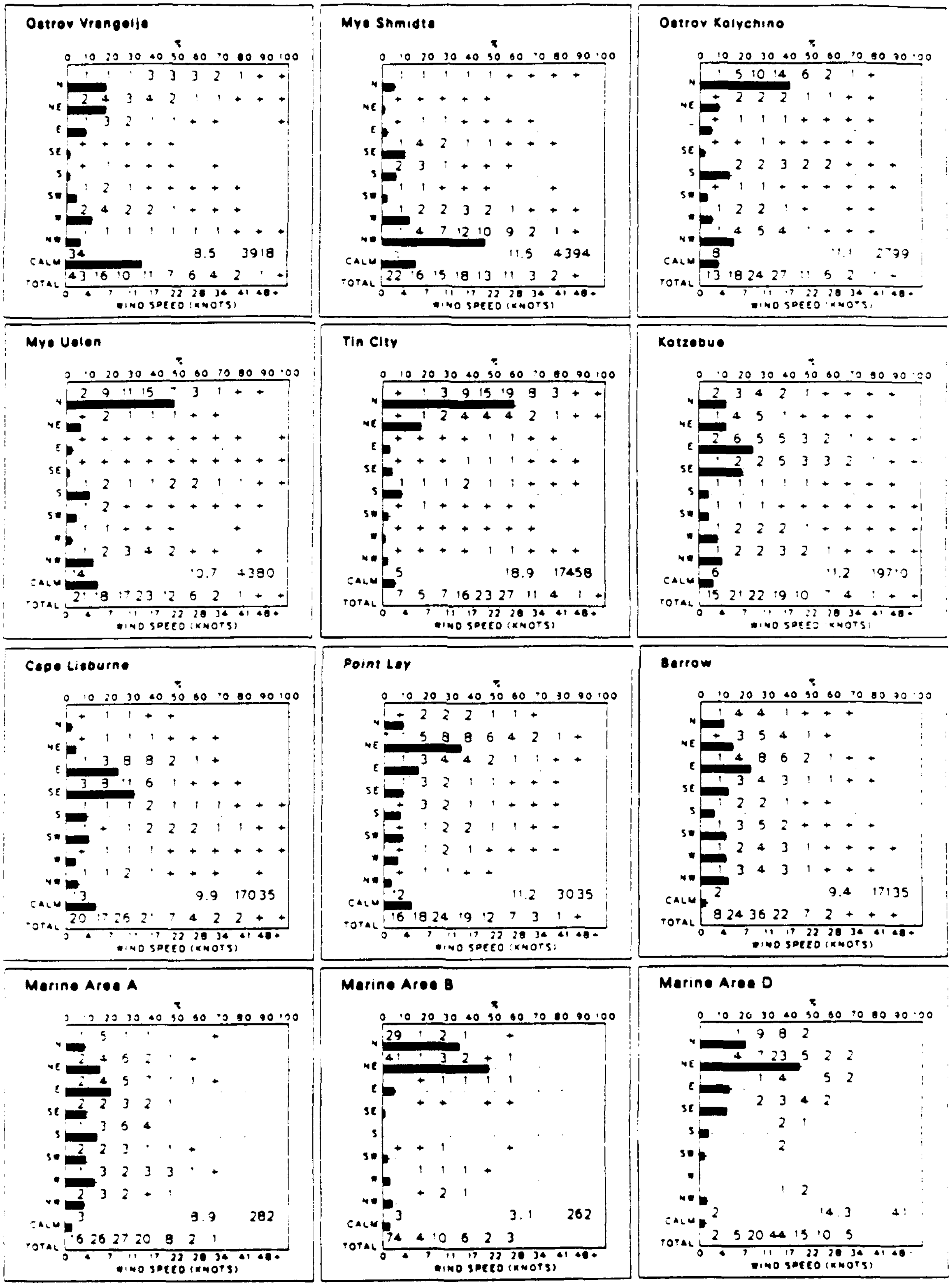


January

After Brower et al. 1988

Figure 25a

Wind Speed/Direction

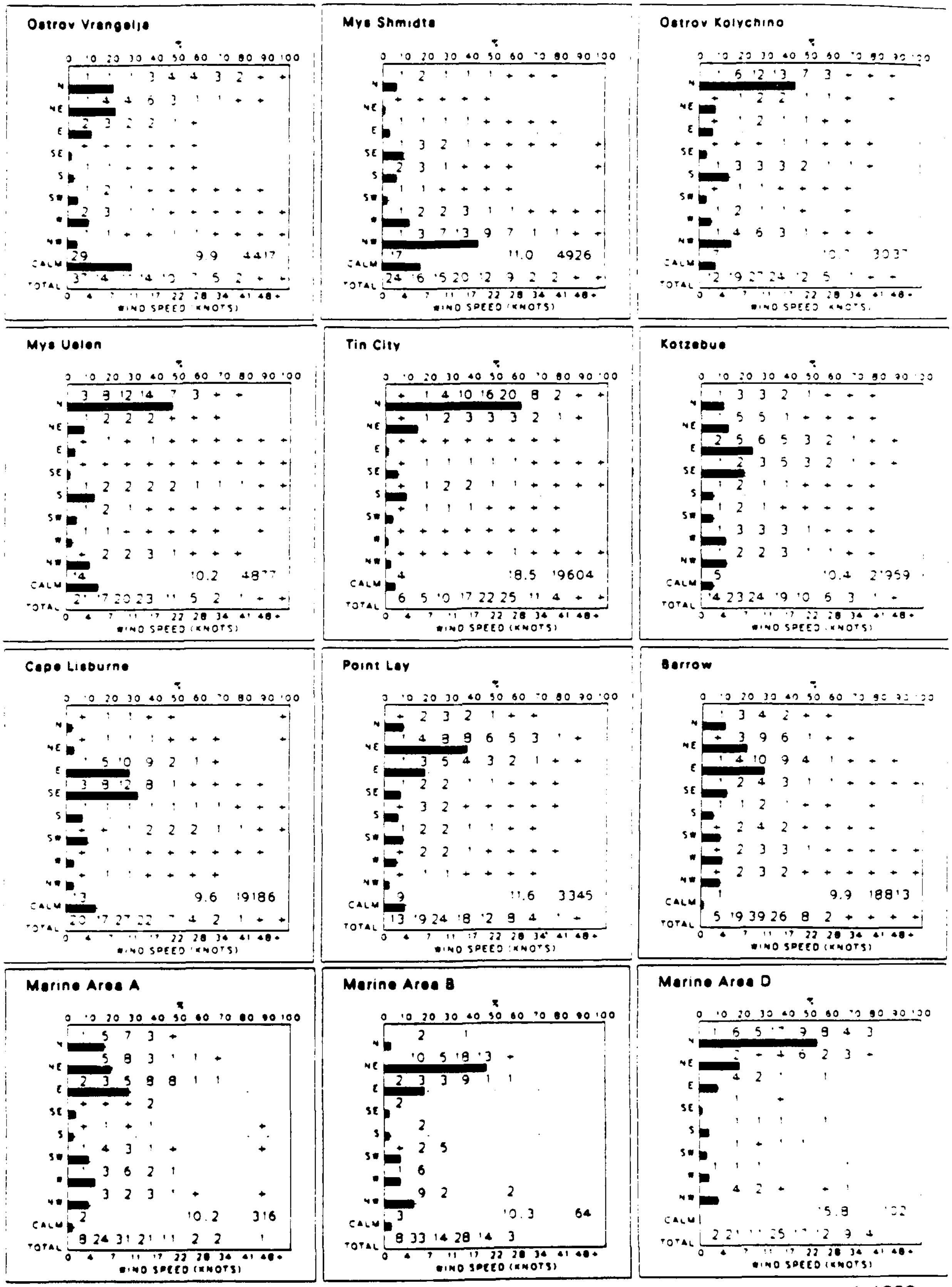


February

After Brower et al. 1988

Figure 25b

Wind Speed/Direction

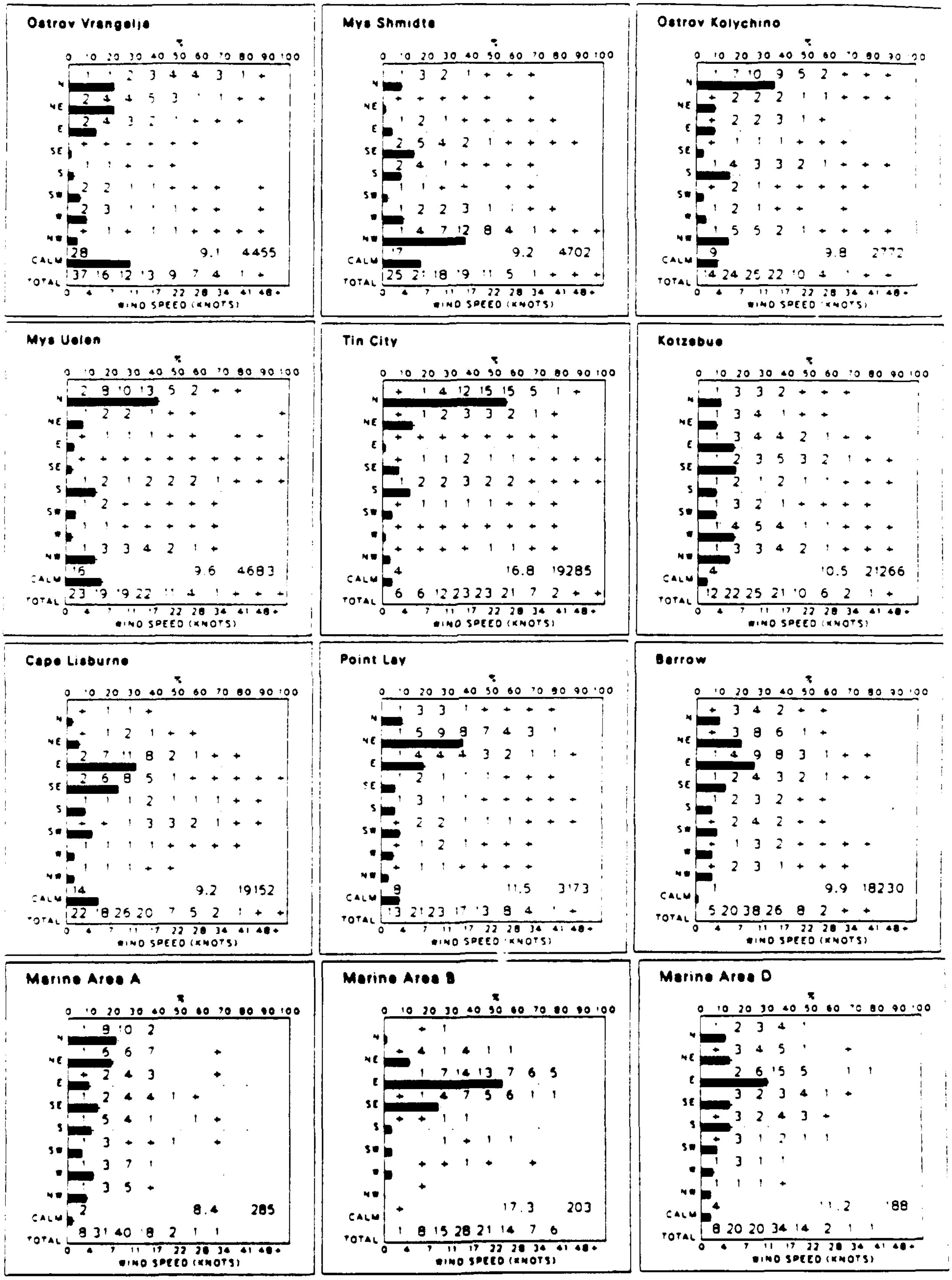


March

After Brower et al. 1988

Figure 25c

Wind Speed/Direction

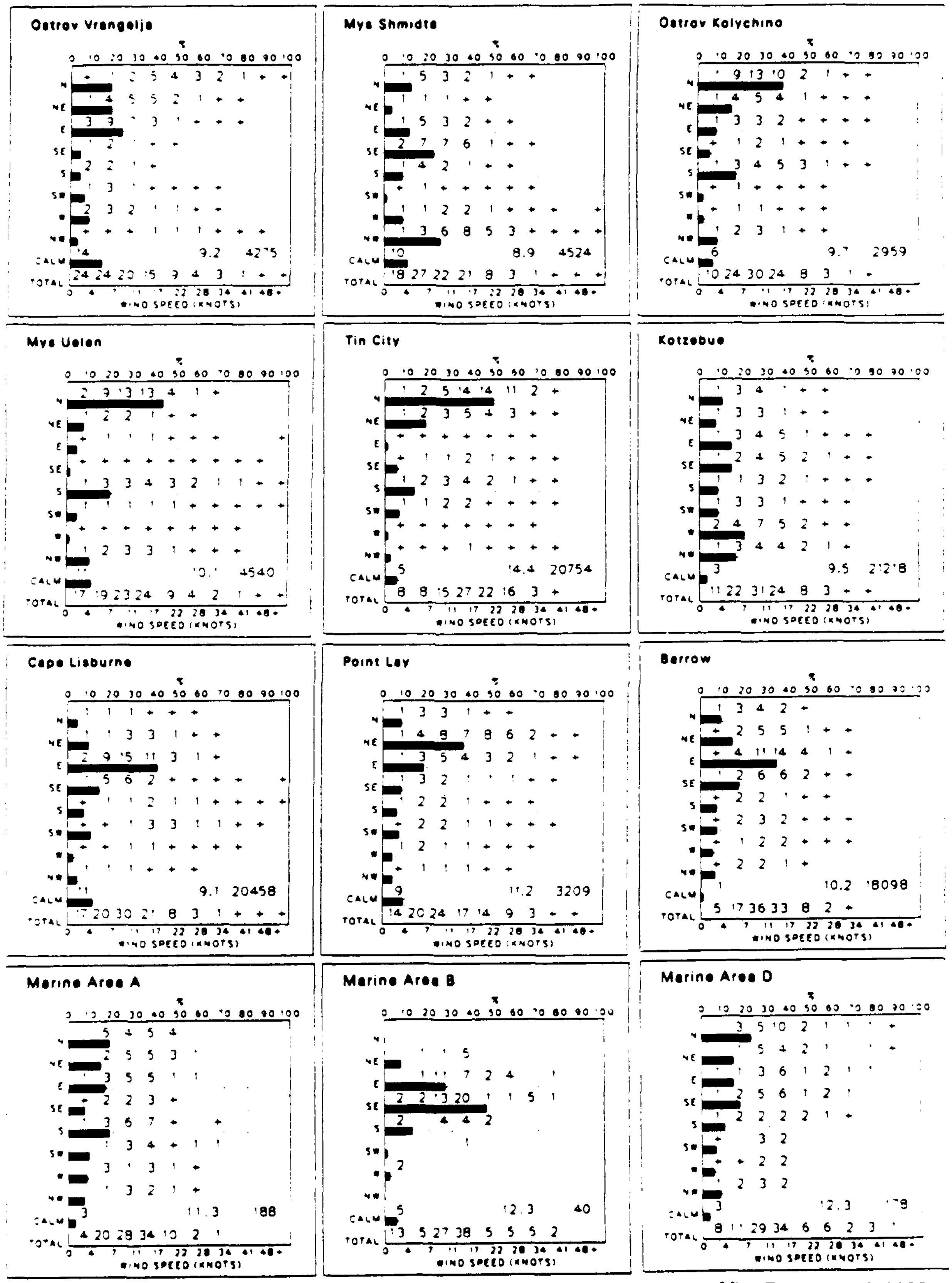


April

After Brower et al. 1988

Figure 25d

Wind Speed/Direction

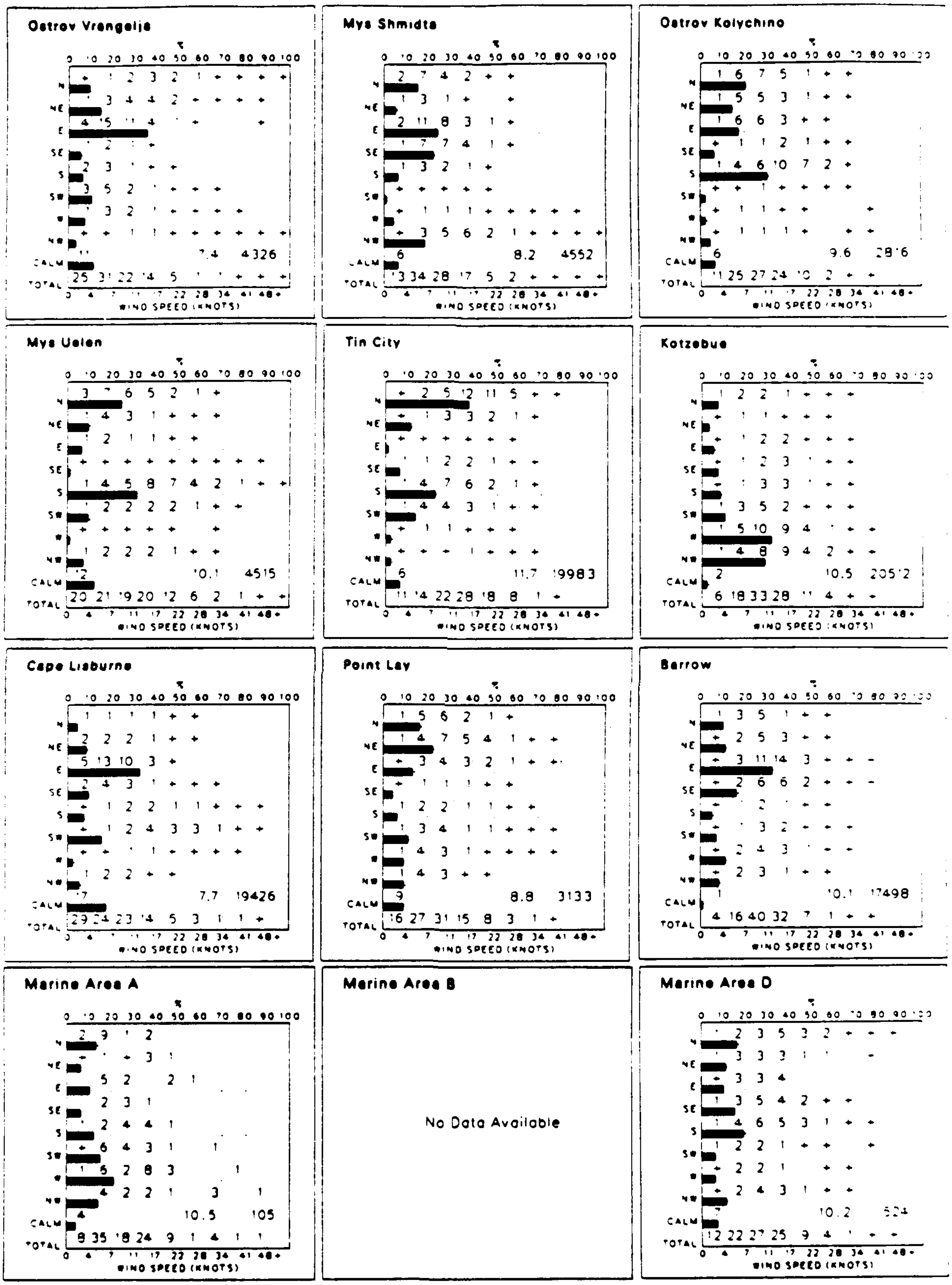


May

After Brower et al. 1988

Figure 25e

Wind Speed/Direction

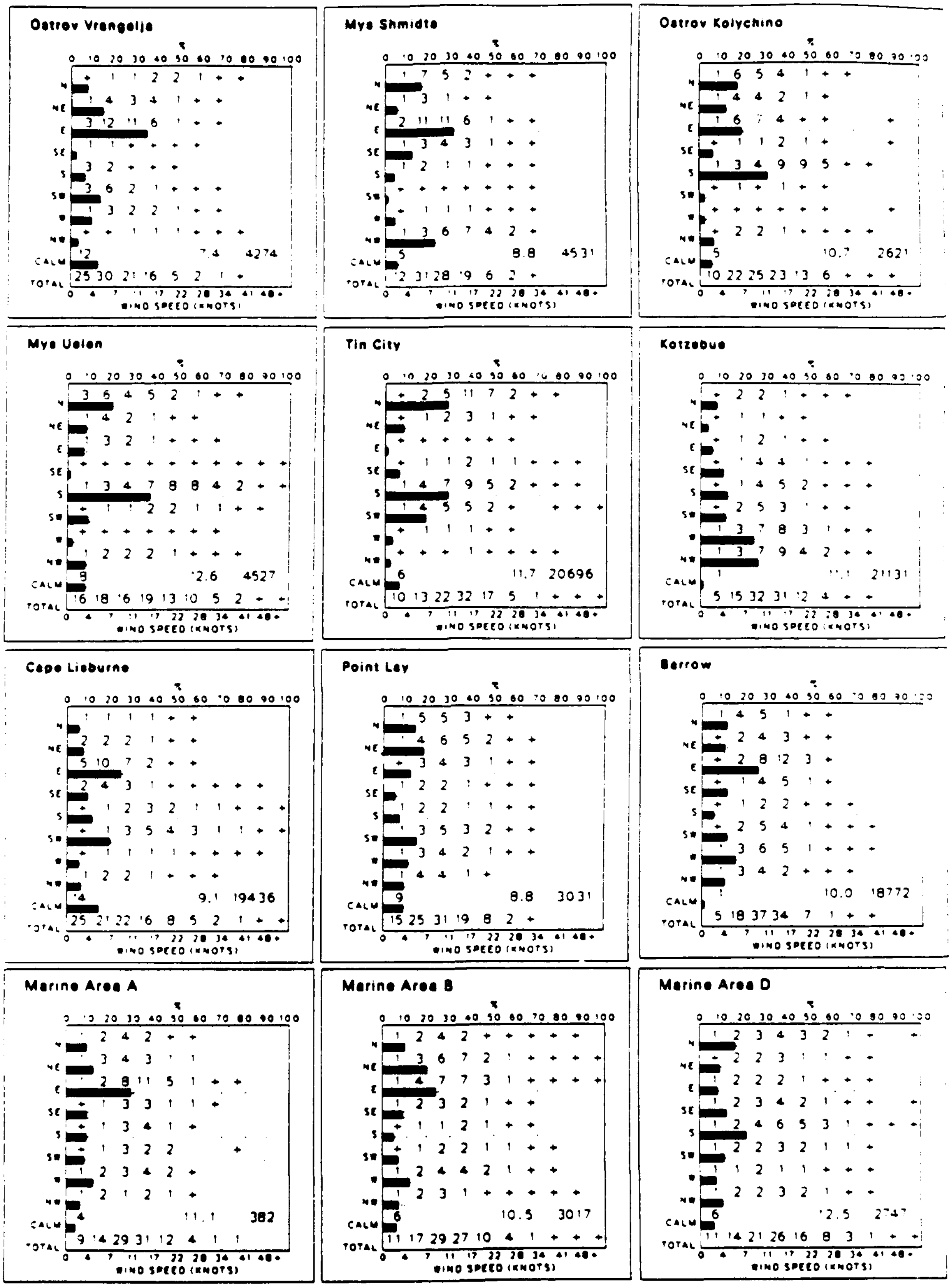


June

After Brower et al. 1988

Figure 25f

Wind Speed/Direction

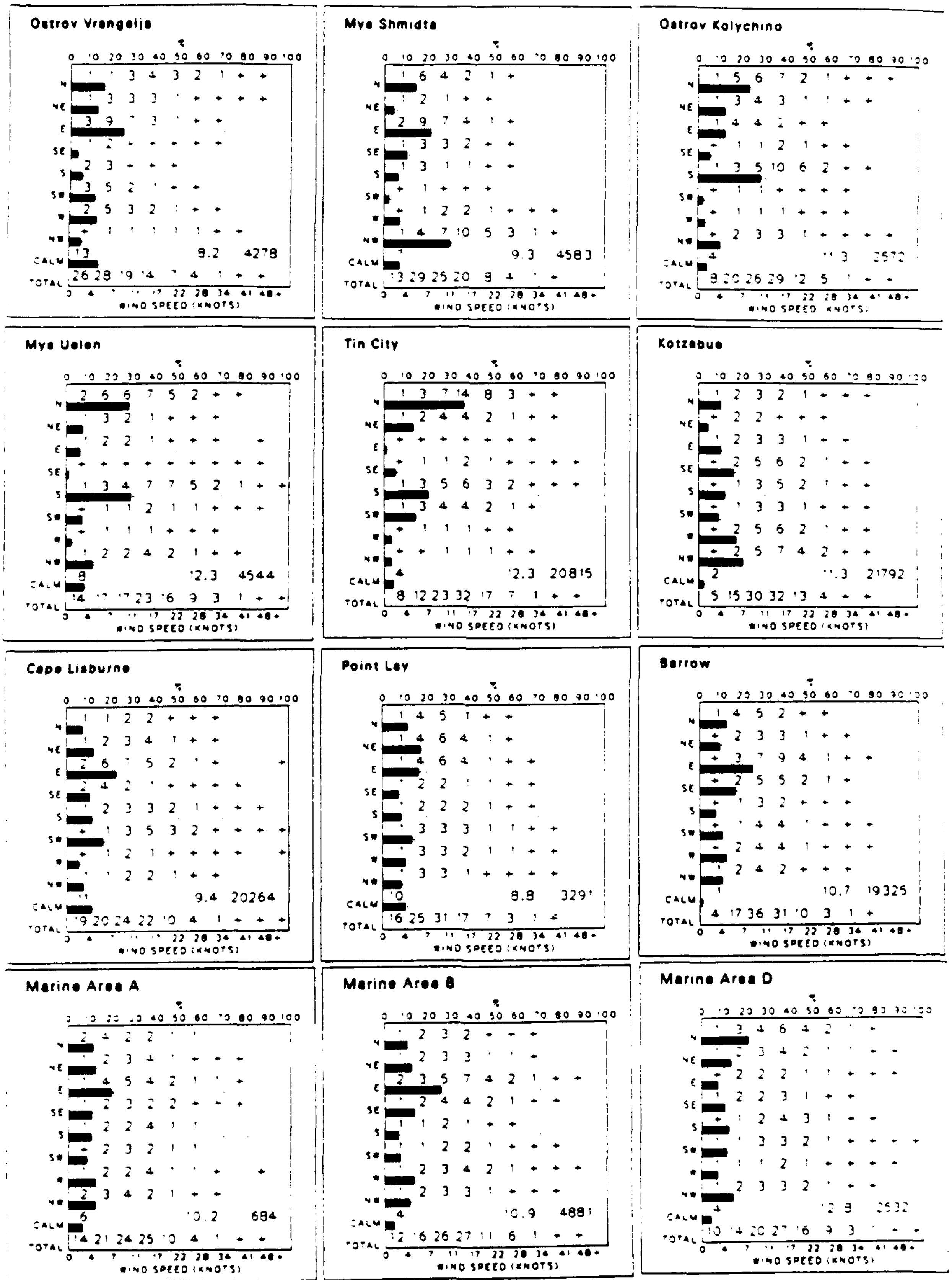


July

After Brower et al. 1988

Figure 25g

Wind Speed/Direction

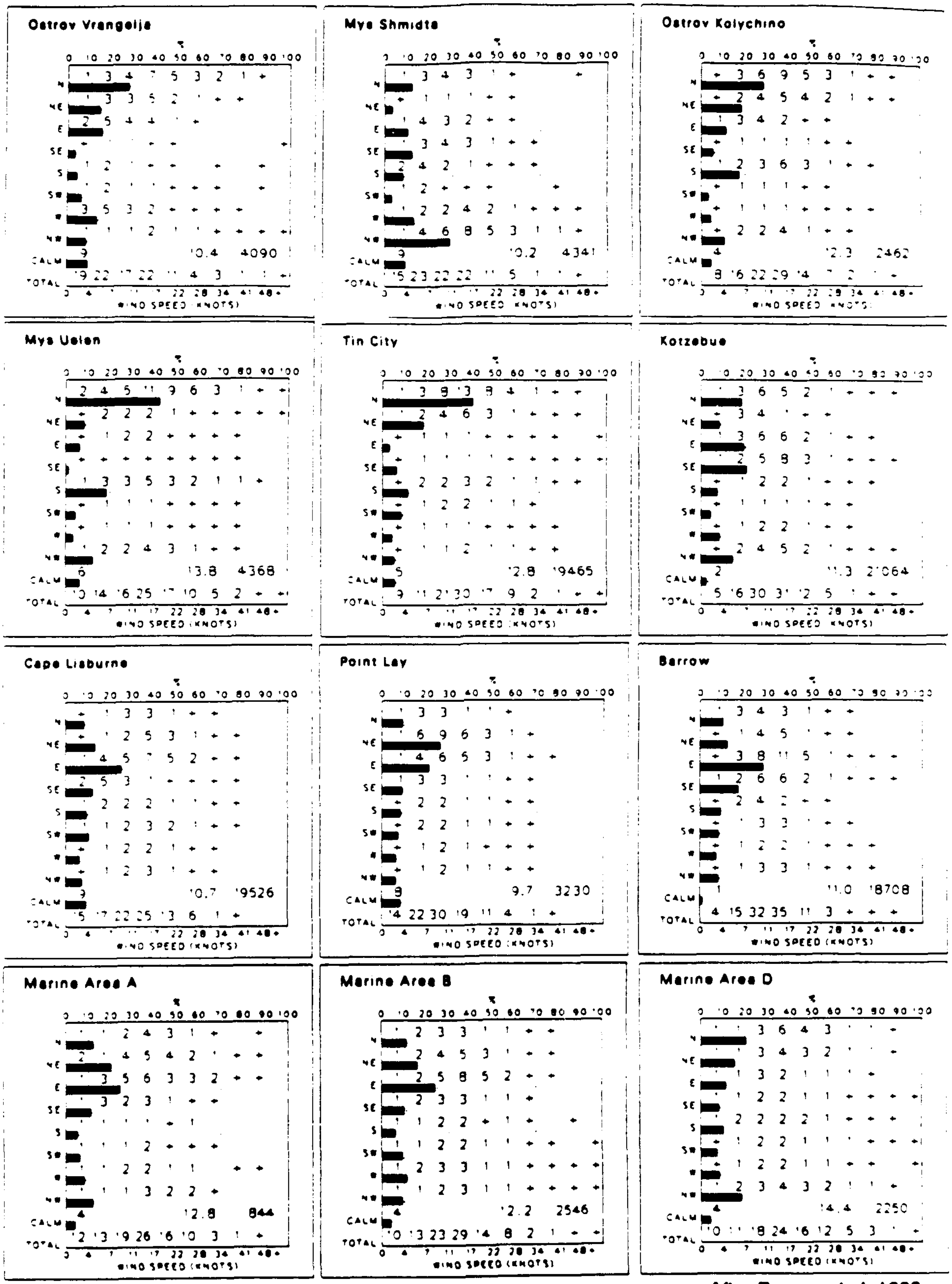


August

After Brower et al. 1988

Figure 25h

Wind Speed/Direction

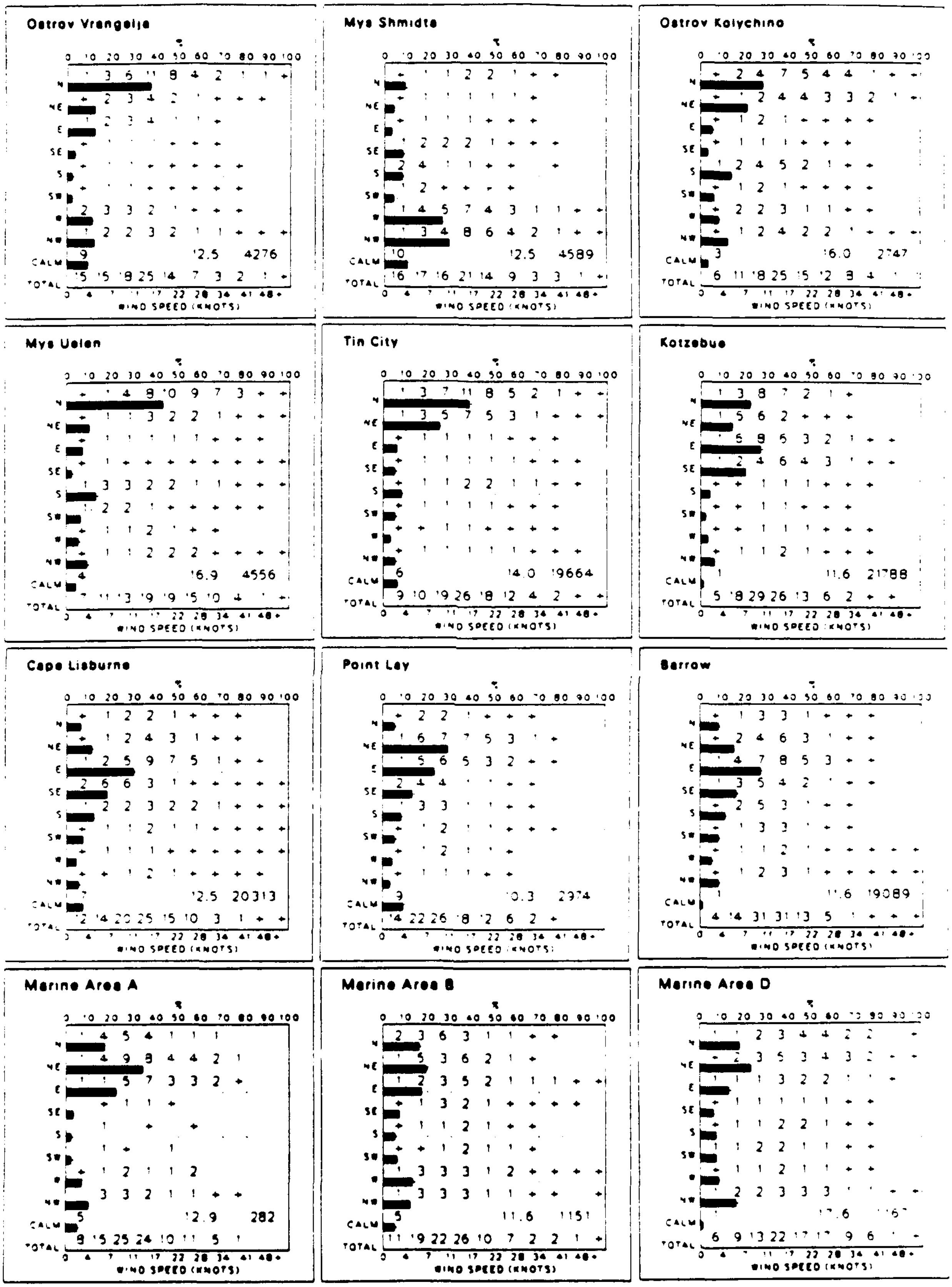


September

After Brower et al. 1988

Figure 25i

Wind Speed/Direction

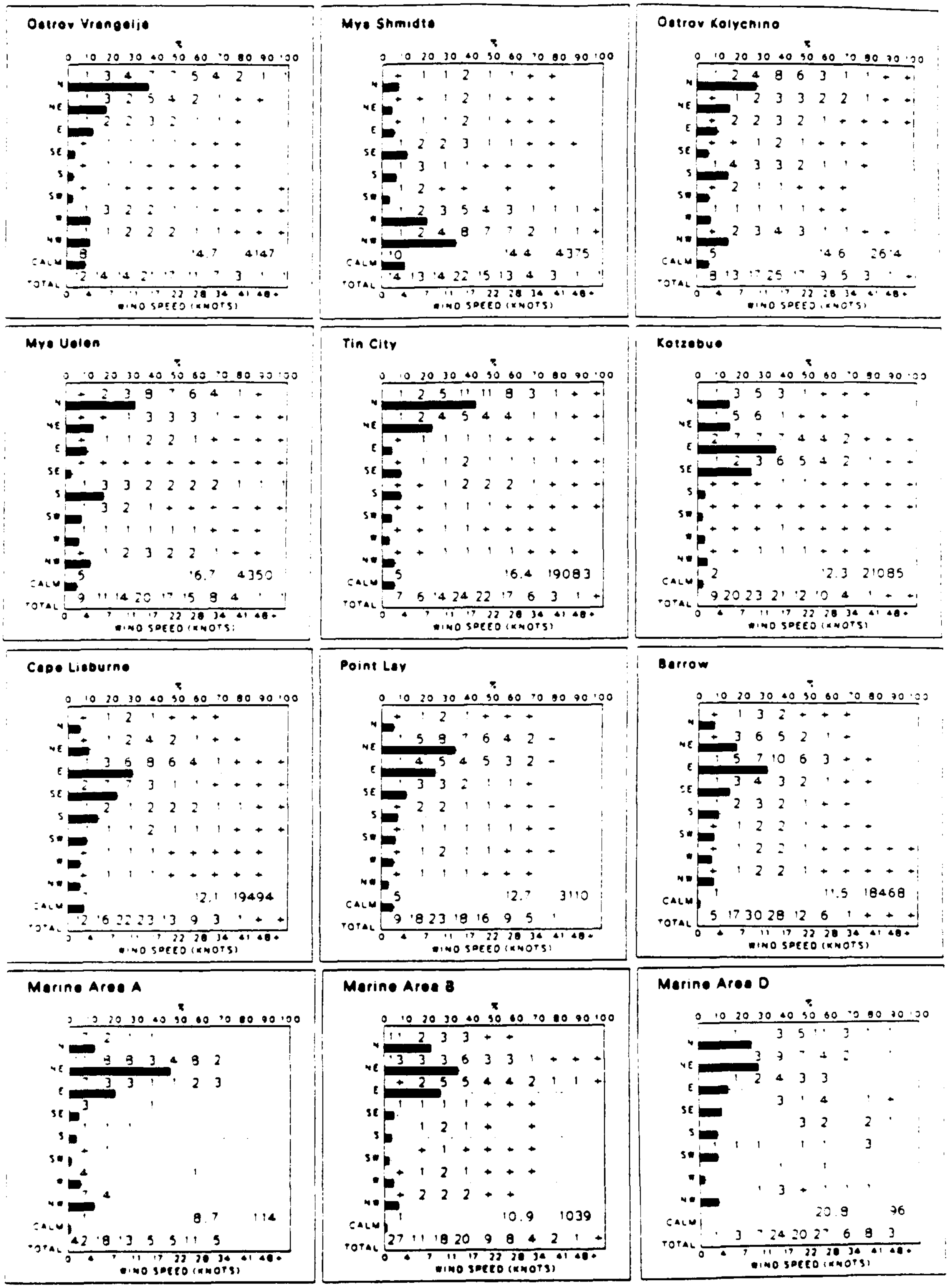


October

After Brower et al. 1988

Figure 25j

Wind Speed/Direction

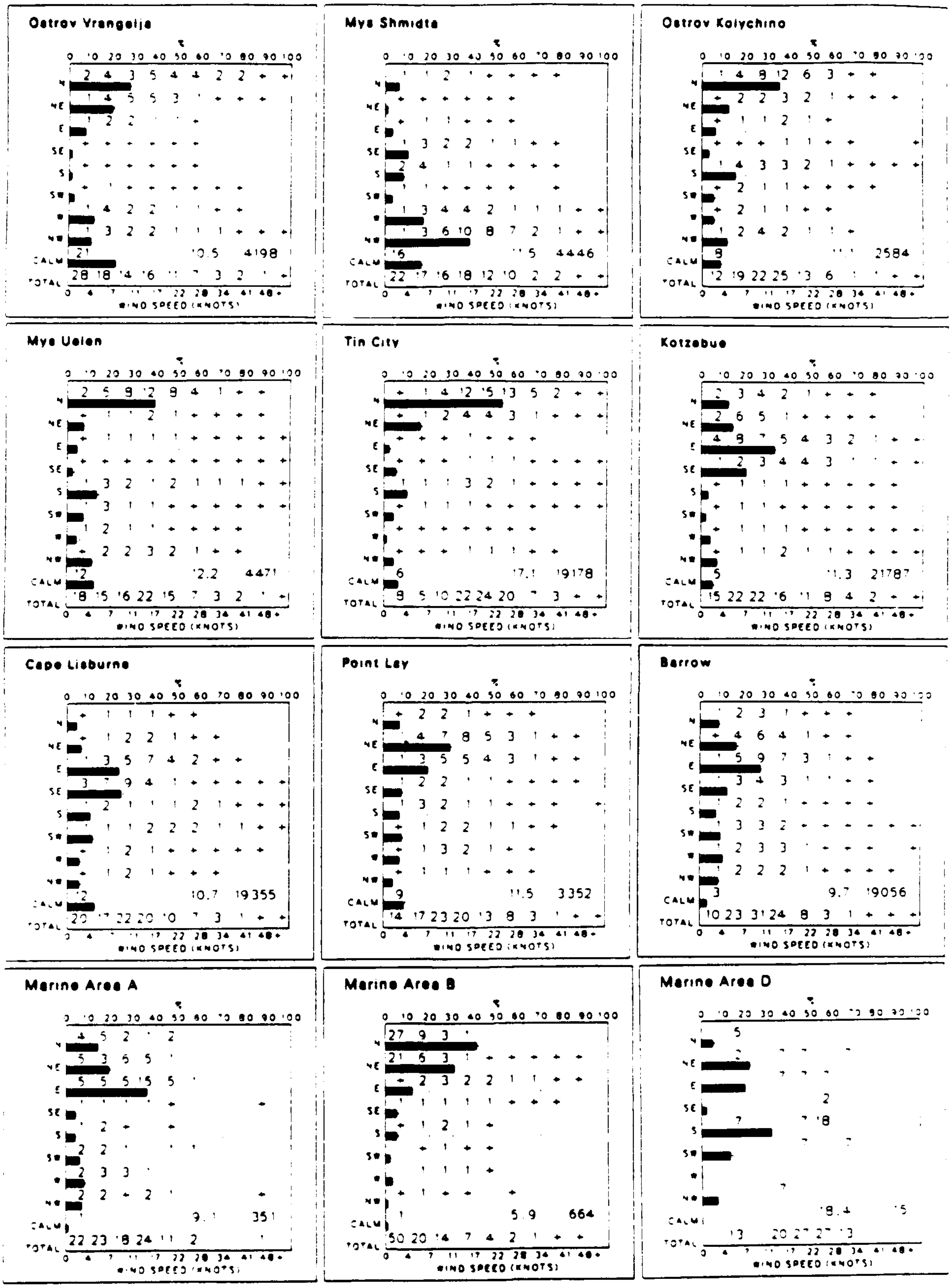


November

After Brower et al. 1988

Figure 25k

Wind Speed/Direction

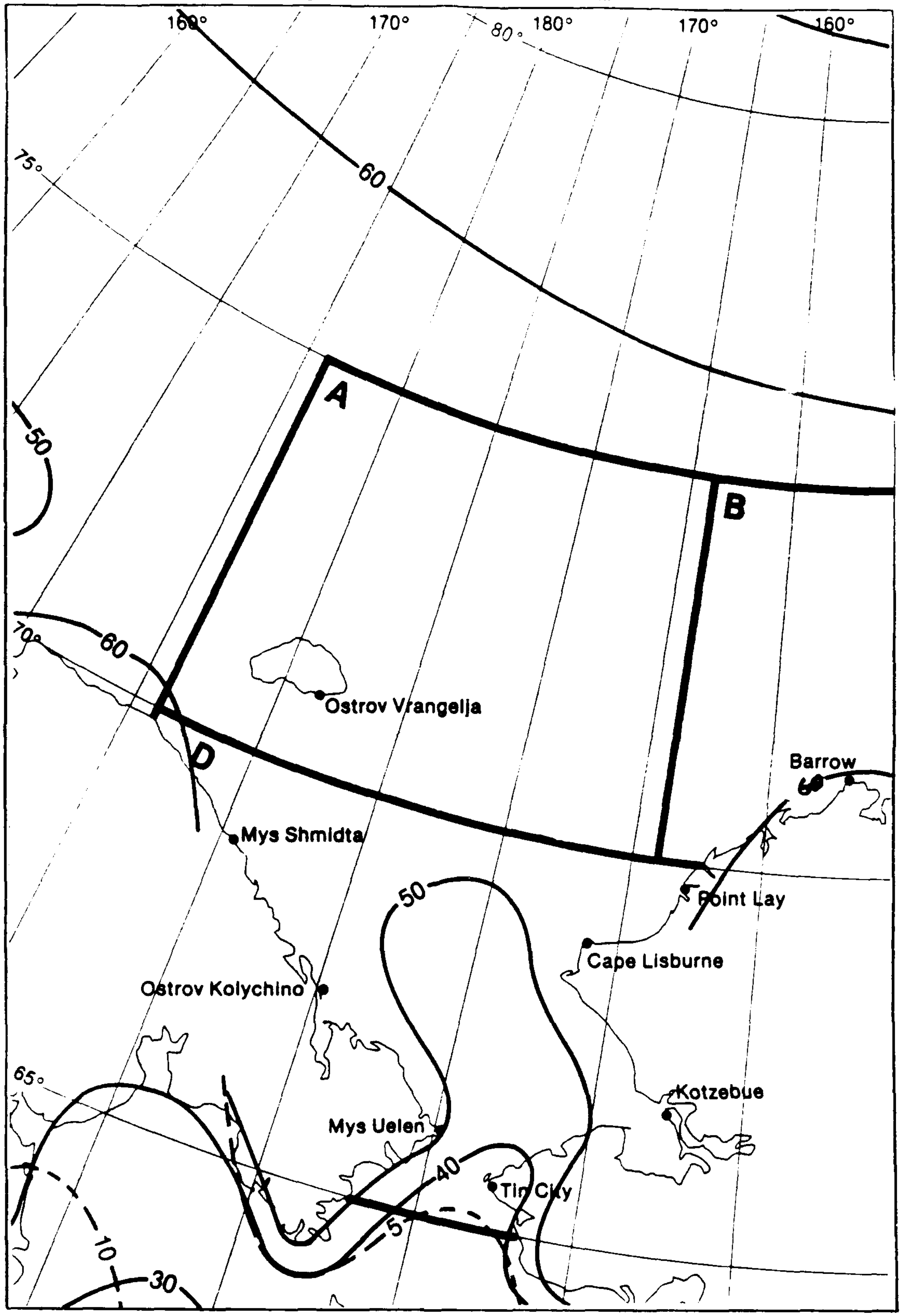


December

After Brower et al. 1988

Figure 251

Wind Speed ≤10 Knots or ≥34 Knots



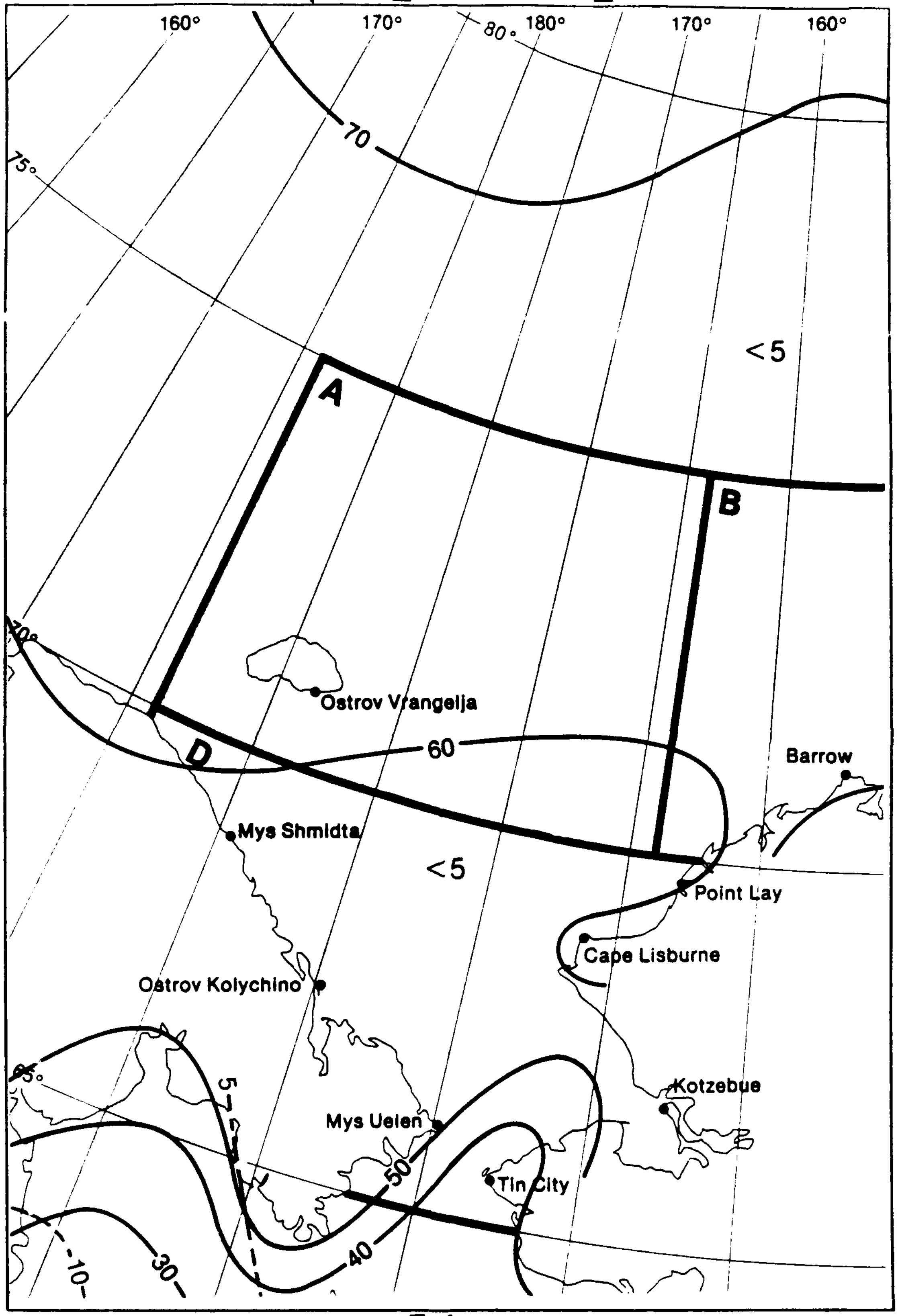
January

After Brower et al. 1988

Legend
% of Wind ≤10 Knots
% of Wind ≥34 Knots

Figure 26a

Wind Speed ≤10 Knots or ≥34 Knots



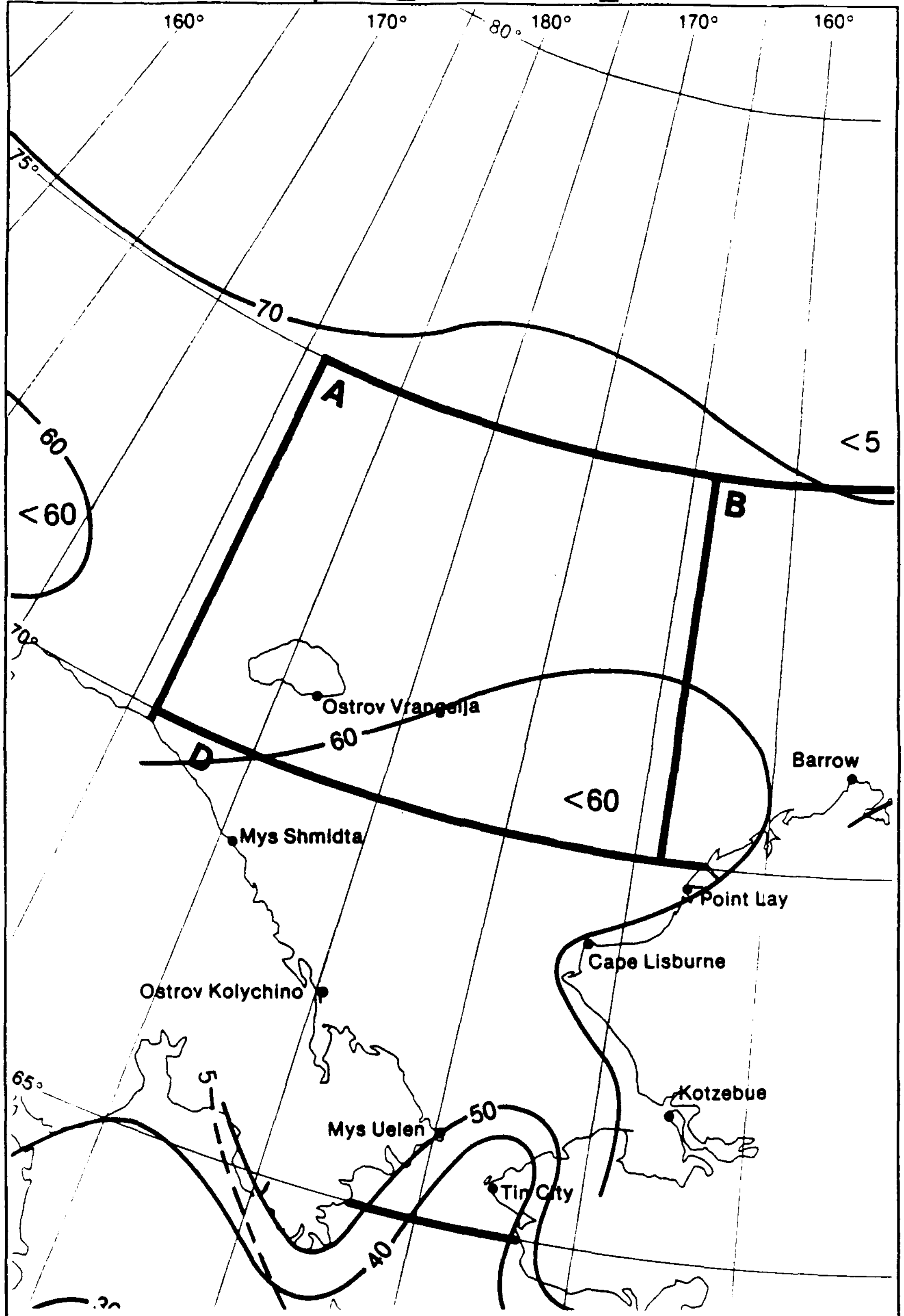
February

After Brower et al. 1988

Legend	
———	% of Wind ≤10 Knots
- - - - -	% of Wind ≥34 Knots

Figure 26b

Wind Speed ≤10 Knots or ≥34 Knots



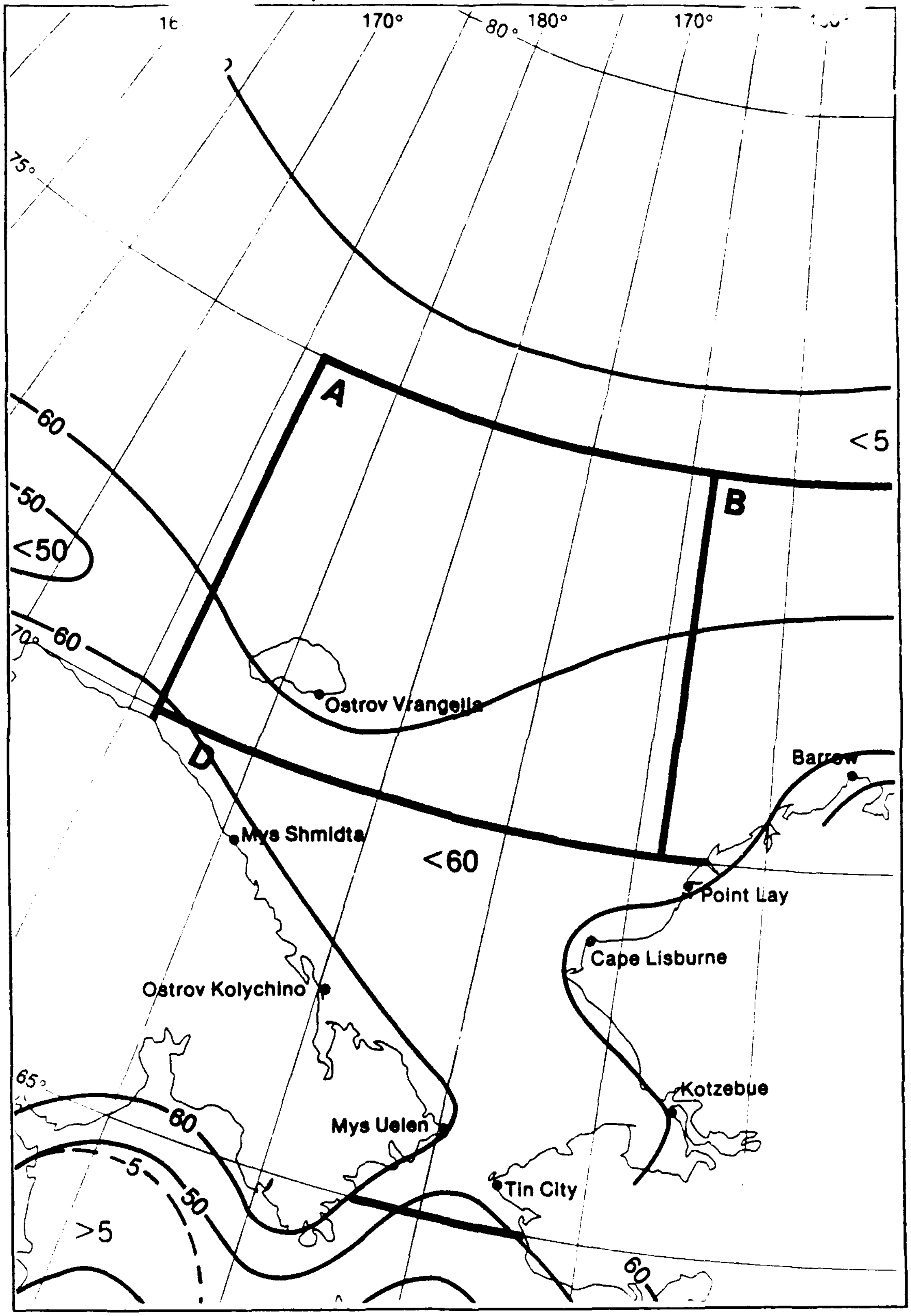
March

After Brower et al. 1988

Legend
% of Wind ≤10 Knots
% of Wind ≥34 Knots

Figure 26c

~d Speed ≤10 Knots or ≥34 Knots



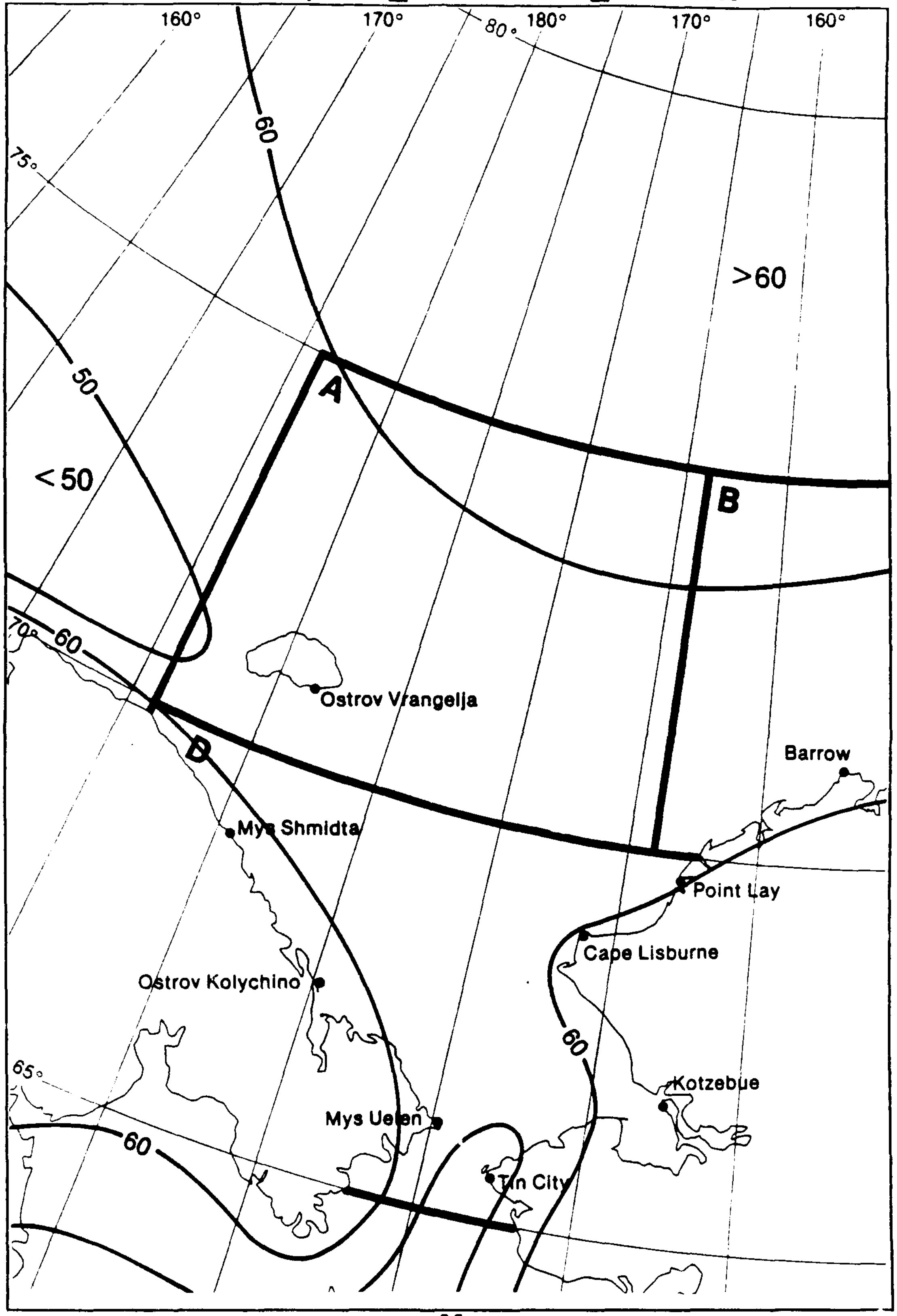
April

After Brower et al. 1988

Legend
% of Wind ≤10 Knots
% of Wind ≥34 Knots

Figure 26d

Wind Speed ≤10 Knots or ≥34 Knots



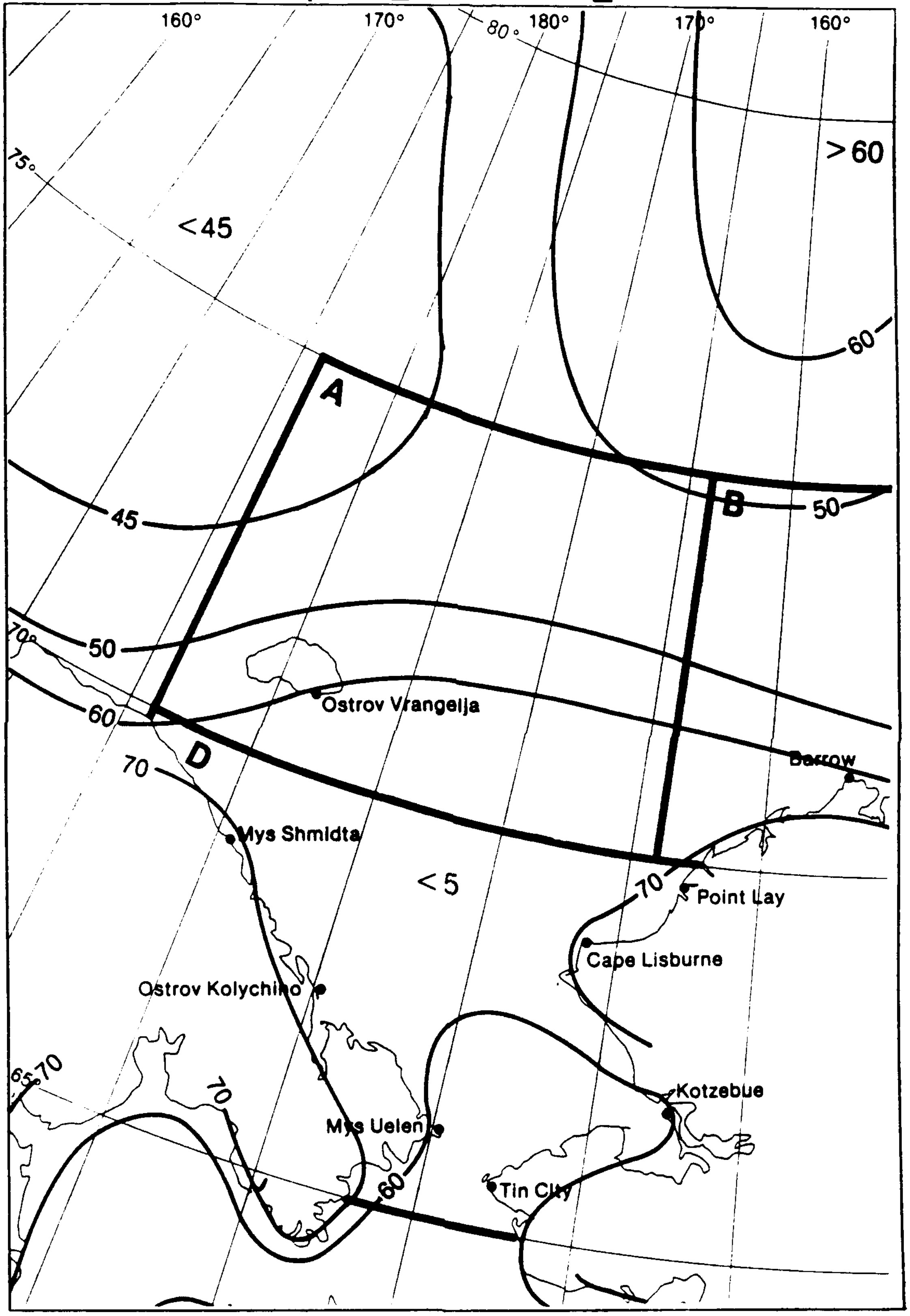
May

After Brower et al. 1988

Legend
- % of Wind ≤10 Knots
- % of Wind ≥34 Knots

Figure 26e

Wind Speed ≤10 Knots or ≥34 Knots



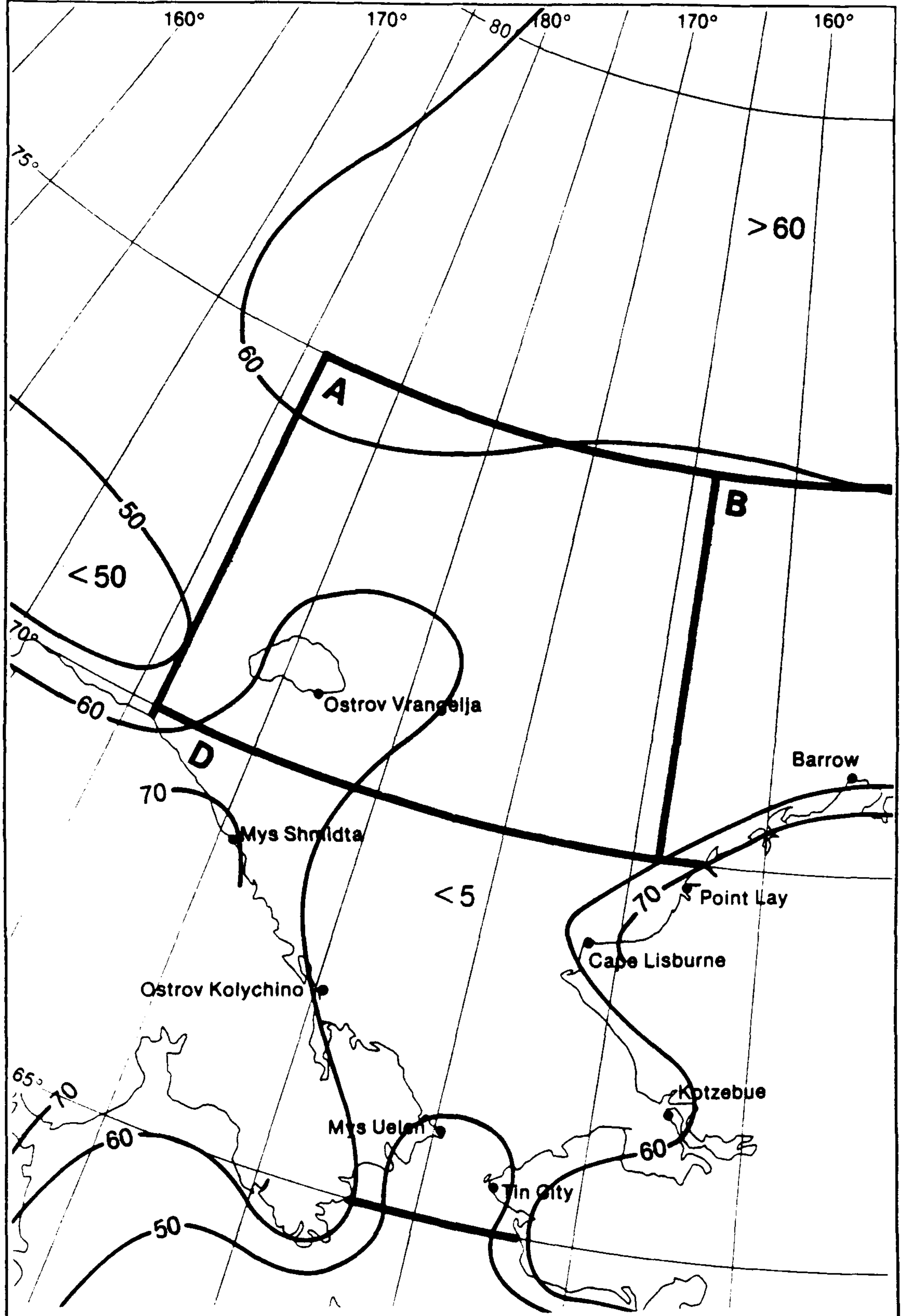
June

After Brower et al. 1988

Legend	
———	% of Wind ≤10 Knots
- - - - -	% of Wind ≥34 Knots

Figure 26f

Wind Speed ≤10 Knots or ≥34 Knots



July

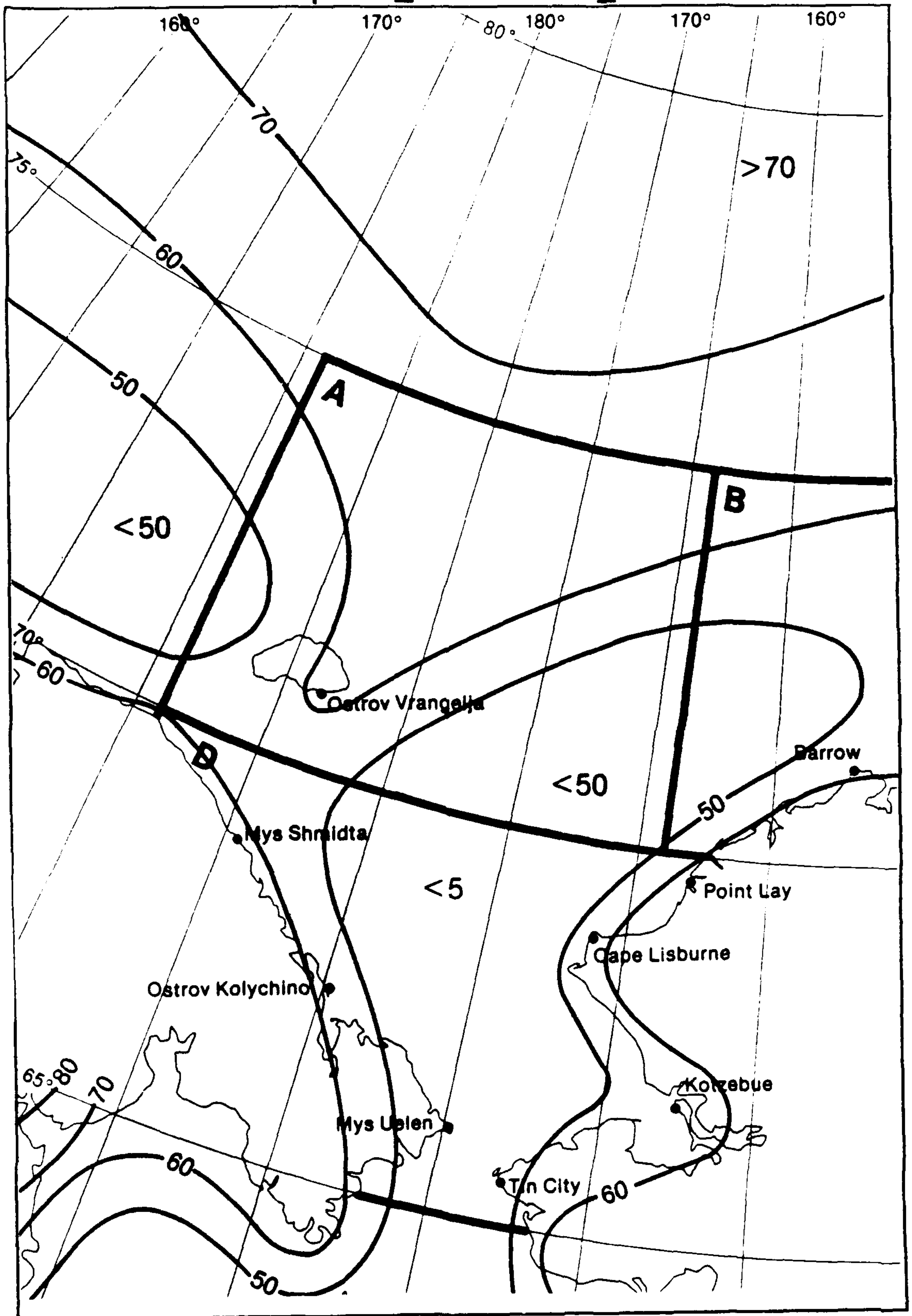
After Brower et al. 1988

Legend

------ % of Wind ≤10 Knots
- - - - - % of Wind ≥34 Knots

Figure 26g

Wind Speed ≤10 Knots or ≥34 Knots



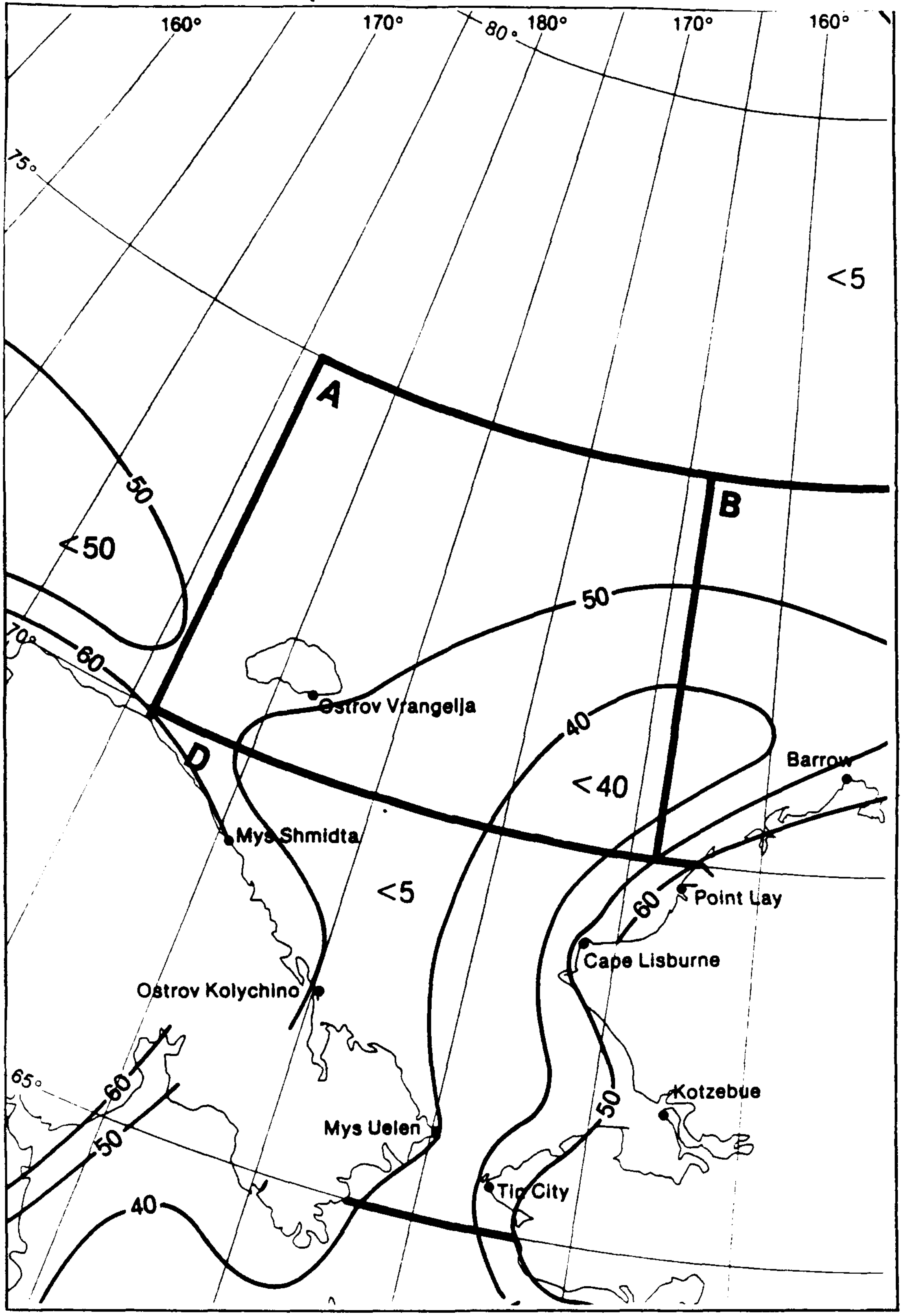
August

After Brower et al. 1988

Legend
------ % of Wind ≤10 Knots
- - - - - % of Wind ≥34 Knots

Figure 26h

Wind Speed ≤10 Knots or ≥34 Knots



September

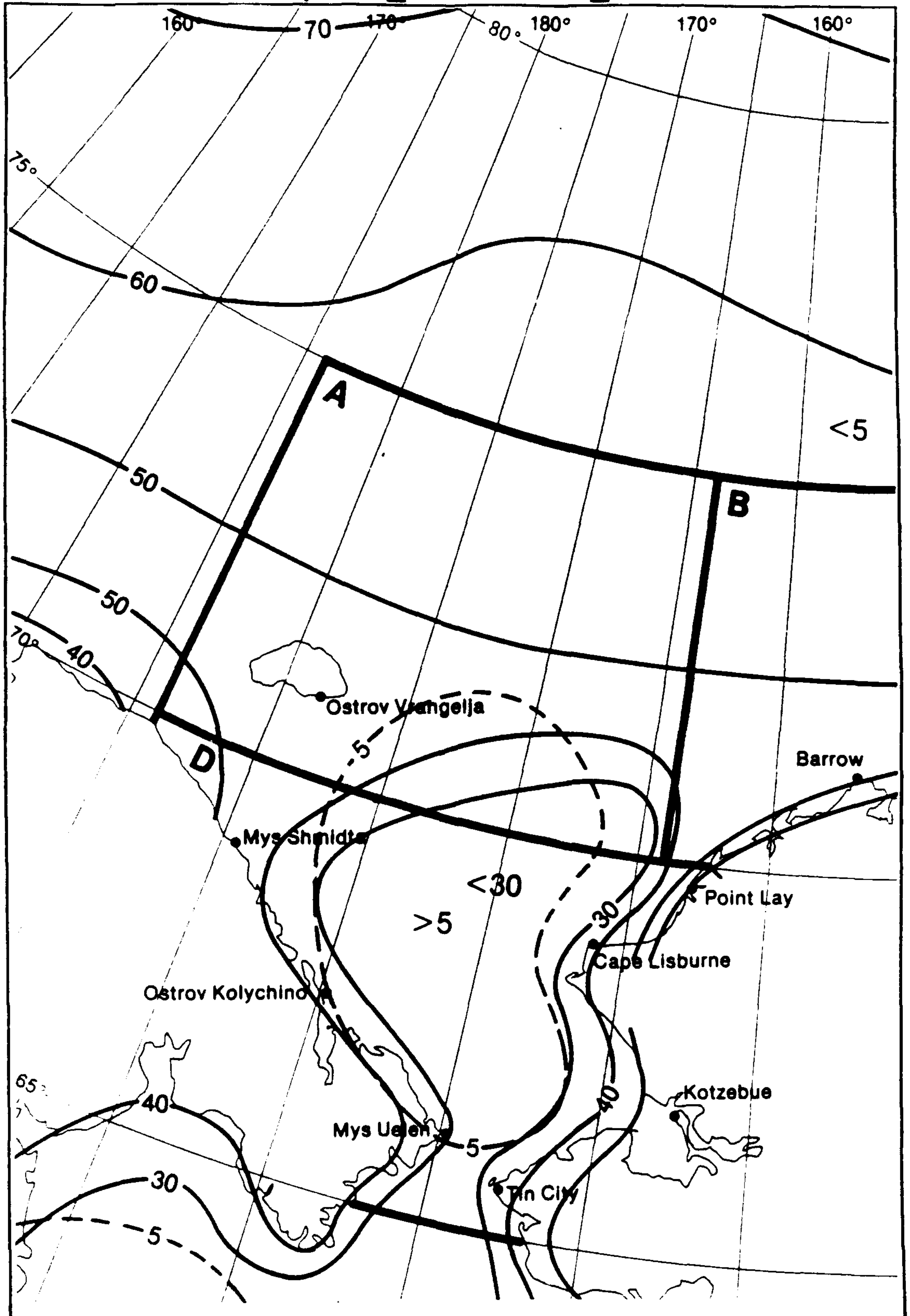
After Brower et al. 1988

Legend

- - - - % of Wind ≤10 Knots
· · · · · % of Wind ≥34 Knots

Figure 26i

Wind Speed ≤10 Knots or ≥34 Knots

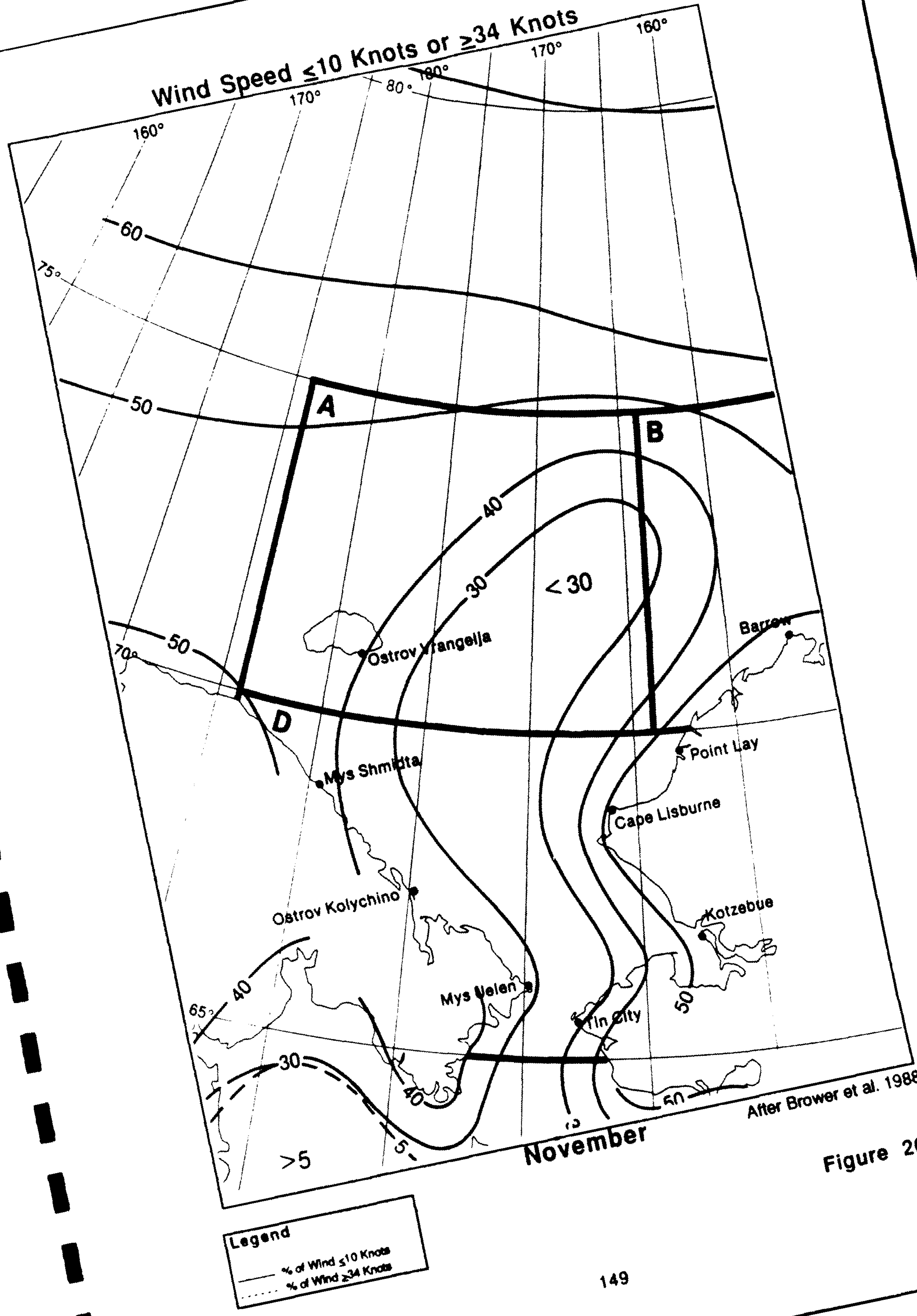


October

After Brower et al. 1988

Legend
——— % of Wind ≤10 Knots
- - - - - % of Wind ≥34 Knots

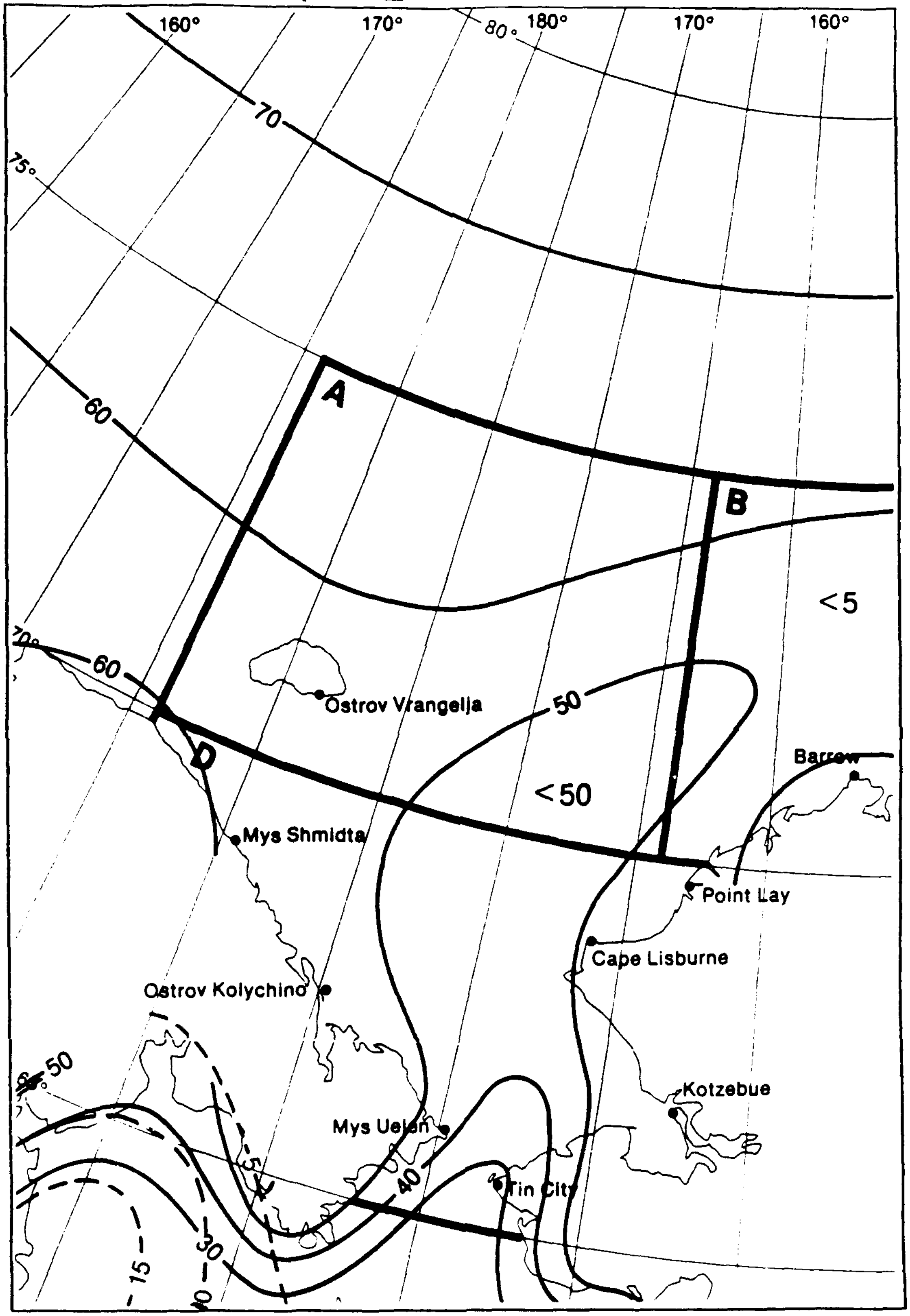
Figure 26j



Wind Speed ≤10 Knots or ≥34 Knots
160°
170°
80°
180°
170°
160°
75°
70°
65°
60
50
50
40
30
<30
40
30
5
>5
40
50
60
A
B
D
Ostrov Vrangelja
Barrow
Mys Shmidta
Point Lay
Cape Lisburne
Ostrov Kolychino
Kotzebue
Mys Uelen
Tin City
After Brower et al. 1988
November
Legend
% of Wind ≤10 Knots
% of Wind ≥34 Knots

Figure 26k

Wind Speed ≤10 Knots or ≥34 Knots

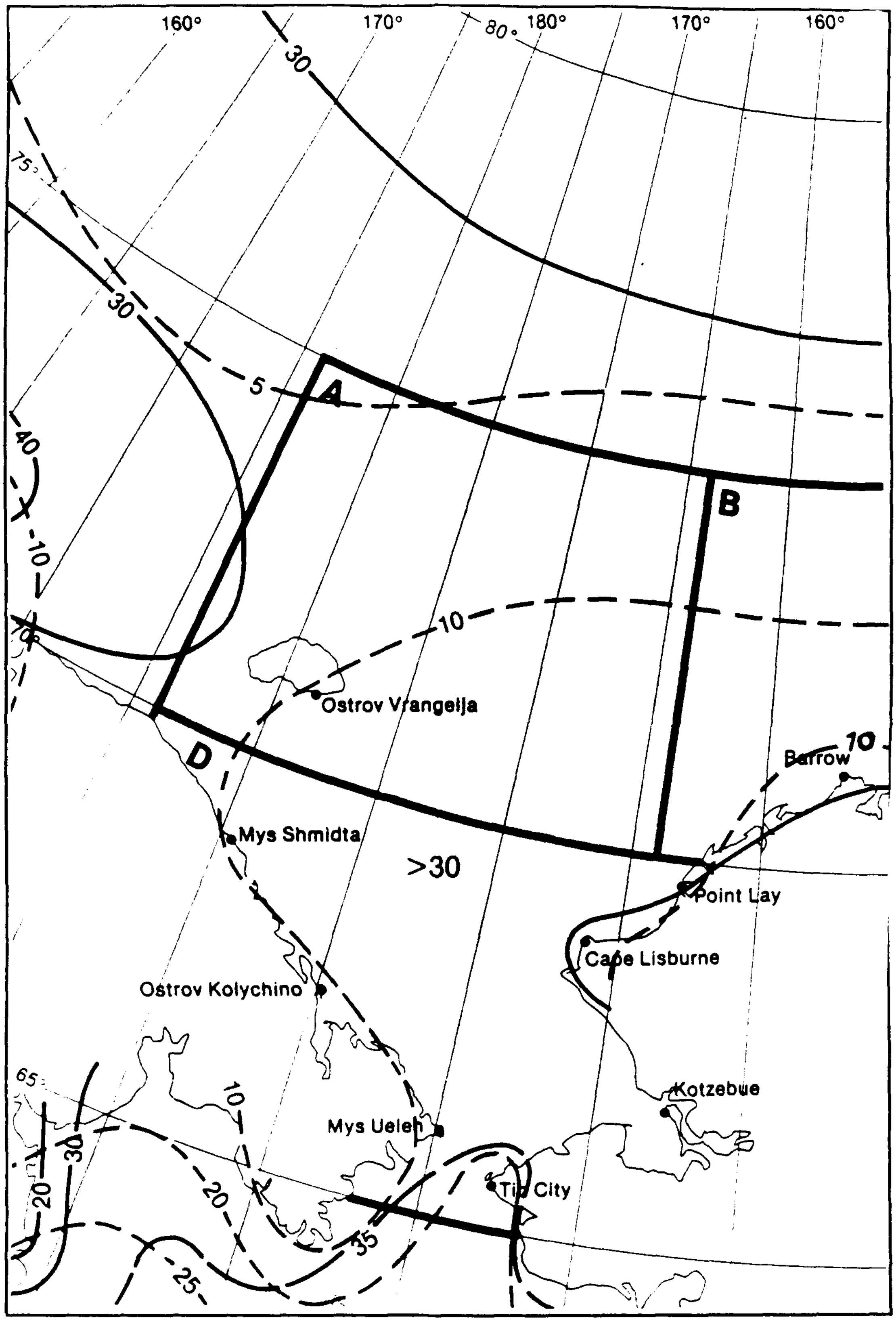


After Brower et al. 1988

Legend
------ % of Wind ≤10 Knots
...... % of Wind ≥34 Knots

Figure 261

Wind Speed 11-21 and 22-33 Knots



January

After Brower et al. 1988

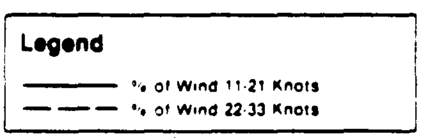
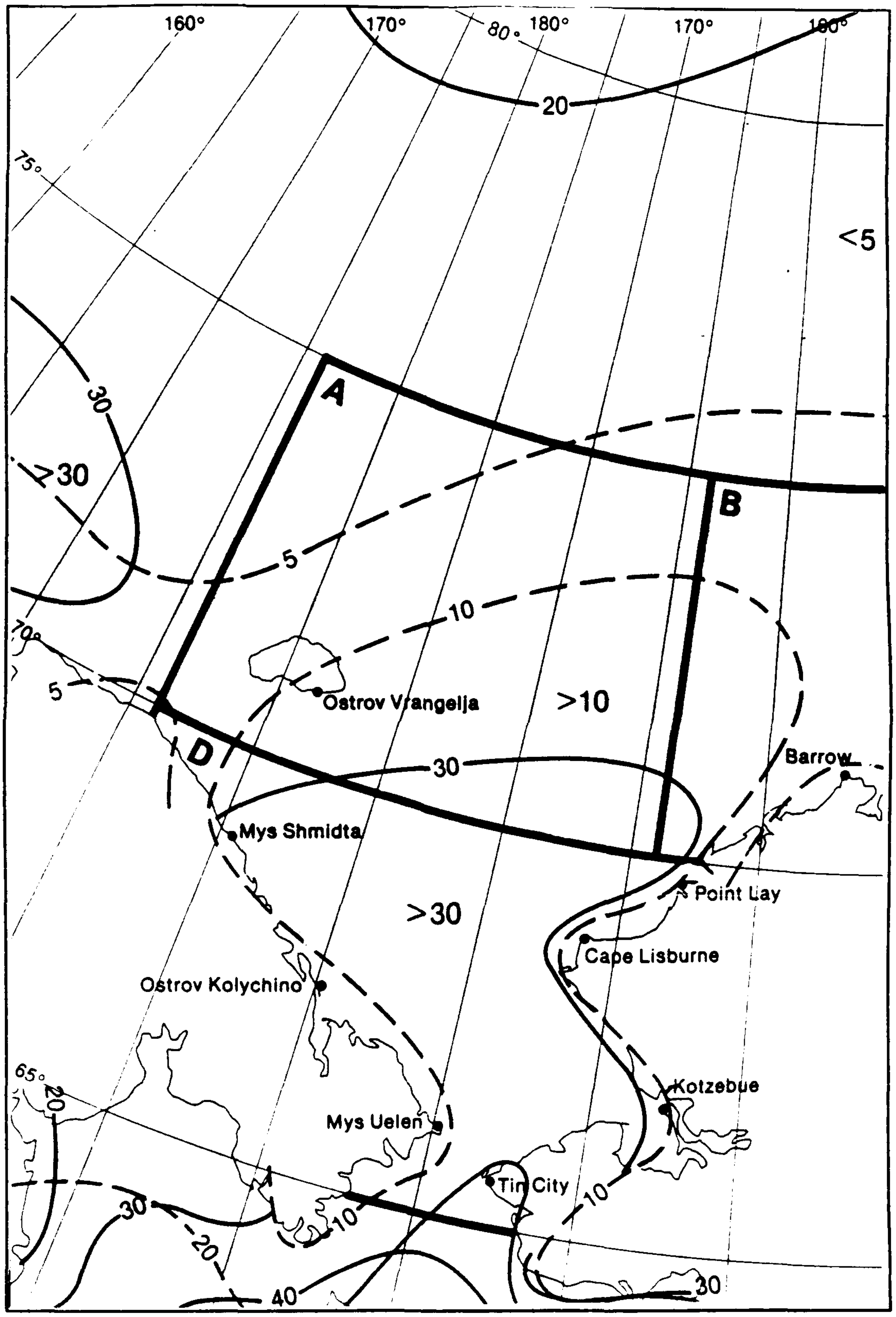


Figure 27a

Wind Speed 11-21 and 22-33 Knots



February

After Brower et al. 1988

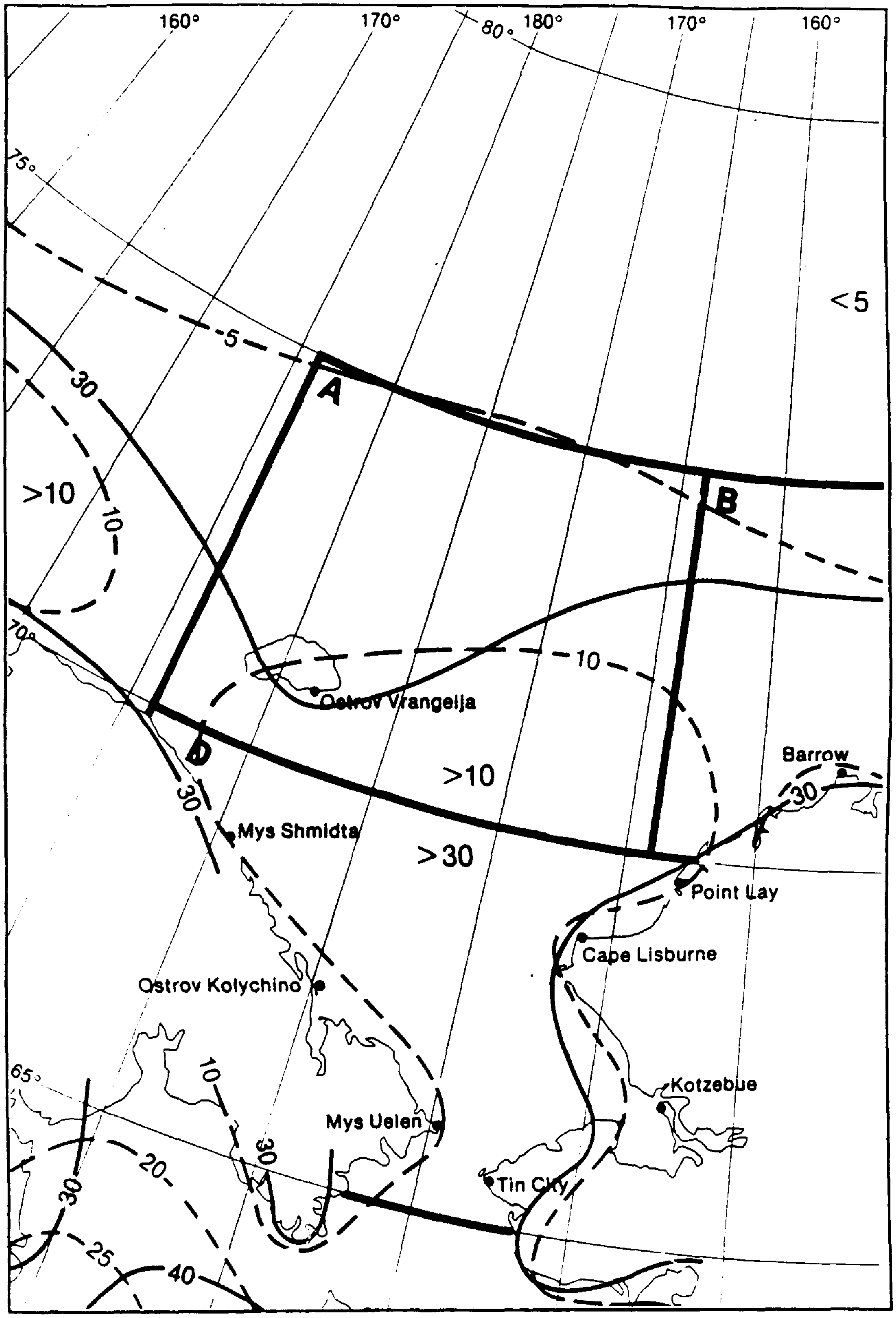
Legend

——— % of Wind 11-21 Knots

– – – % of Wind 22-33 Knots

Figure 27b

Wind Speed 11-21 and 22-33 Knots



March

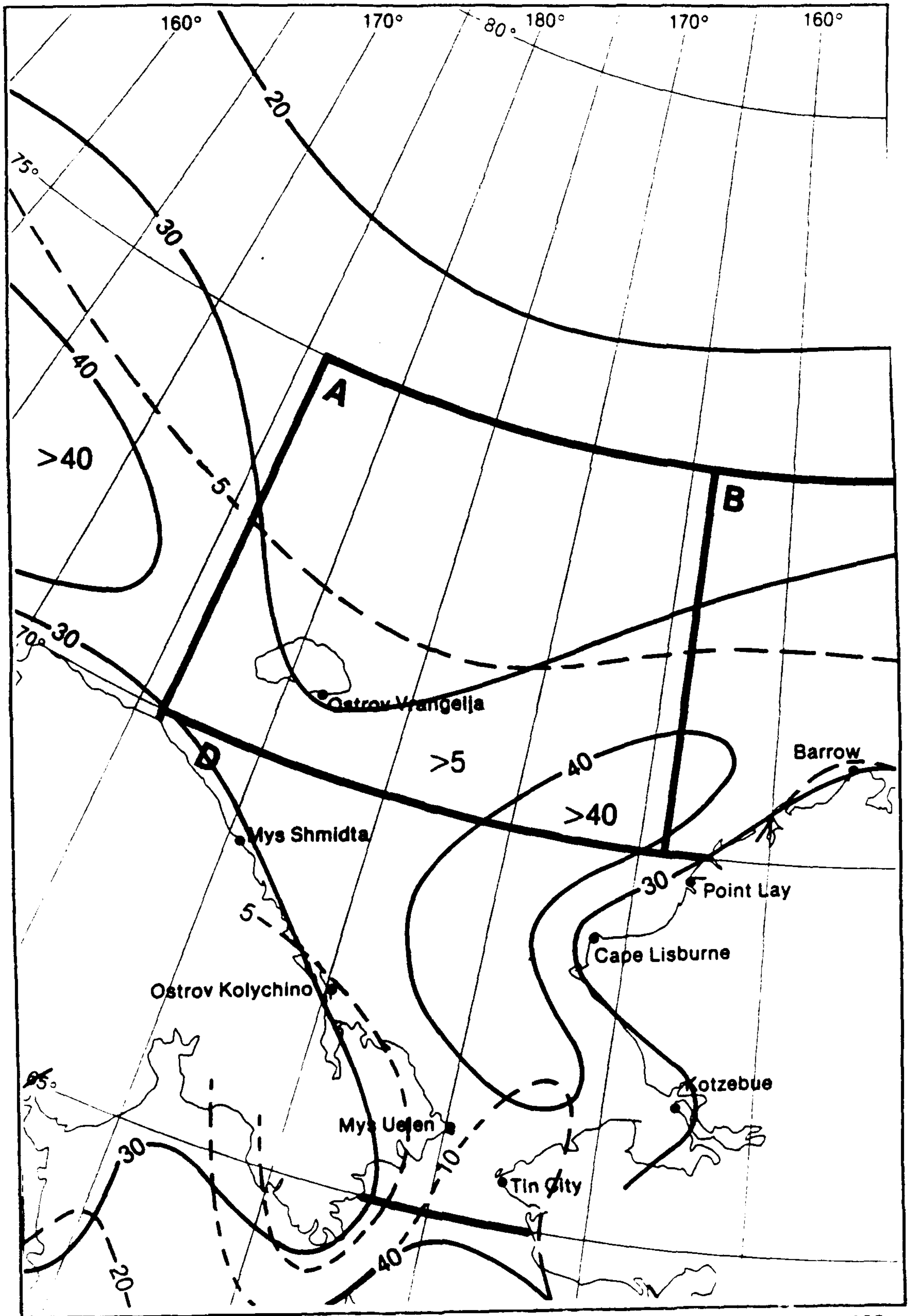
After Brower et al. 1988

Legend

—— % of Wind 11-21 Knots
– – – % of Wind 22-33 Knots

Figure 27c

Wind Speed 11-21 and 22-33 Knots



April

After Brower et al. 1988

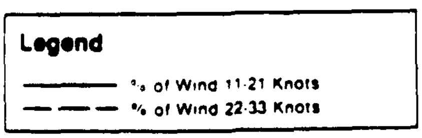
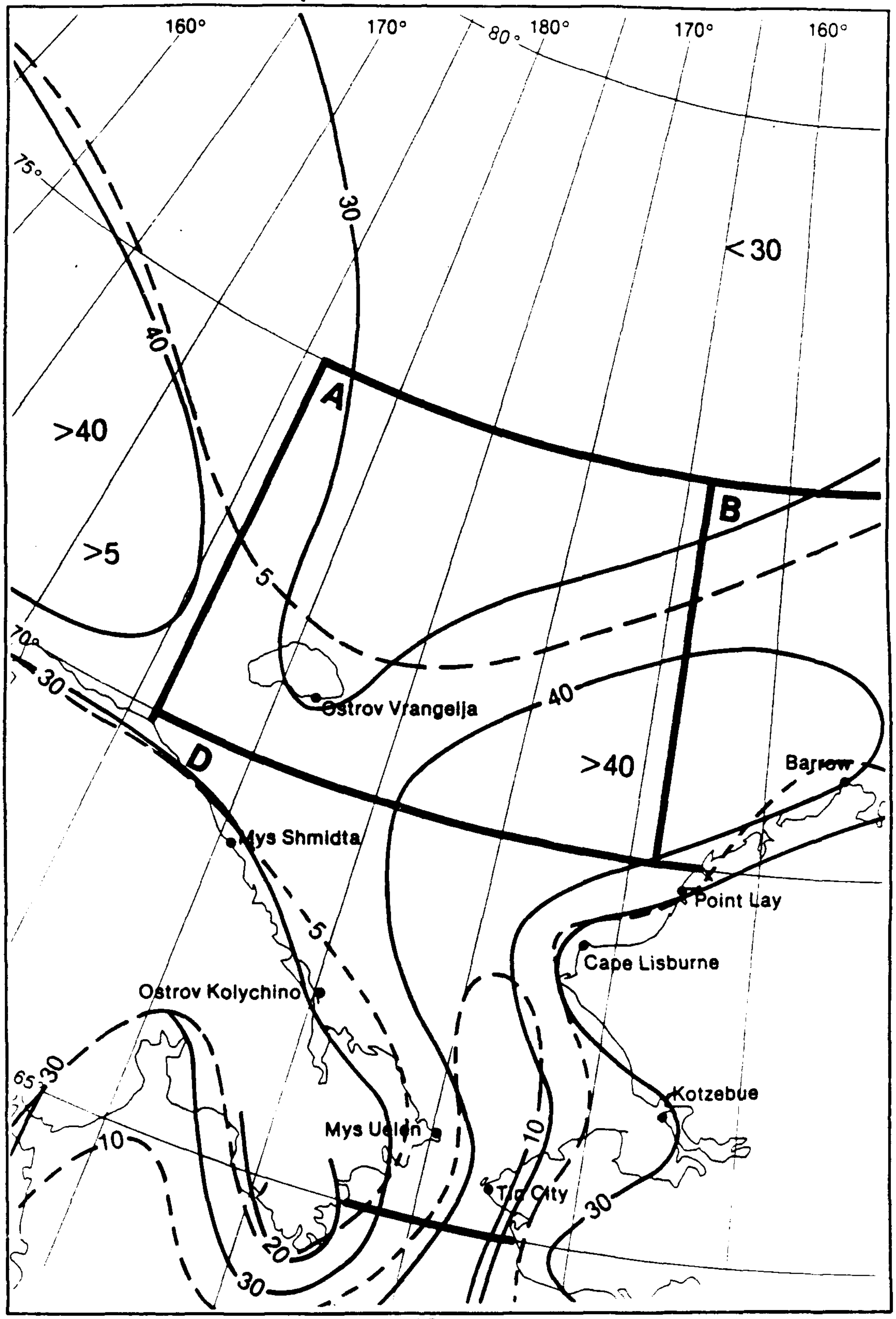


Figure 27d

Wind Speed 11-21 and 22-33 Knots



May

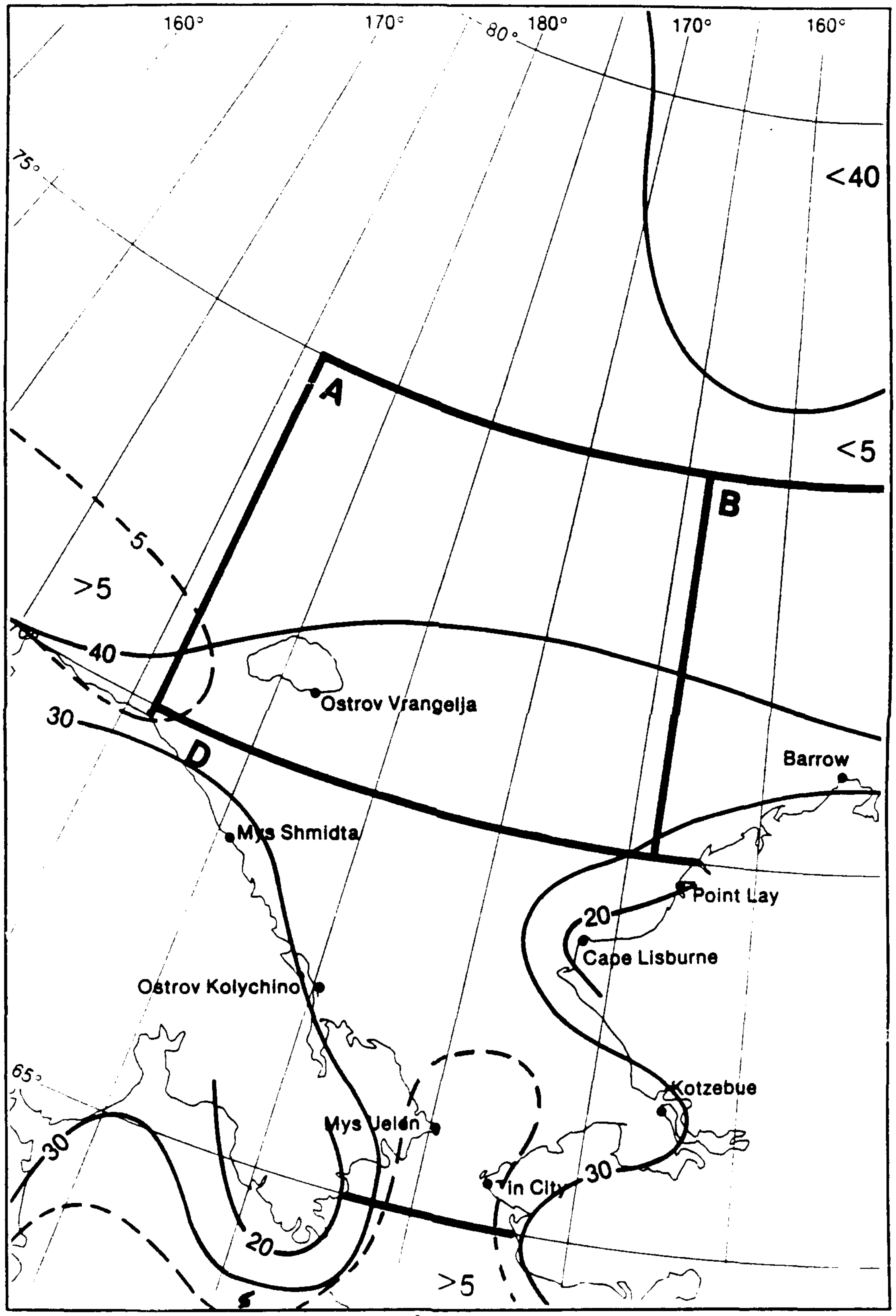
After Brower et al. 1988

Legend

——— % of Wind 11-21 Knots
– – – % of Wind 22-33 Knots

Figure 27e

Wind Speed 11-21 and 22-33 Knots



June

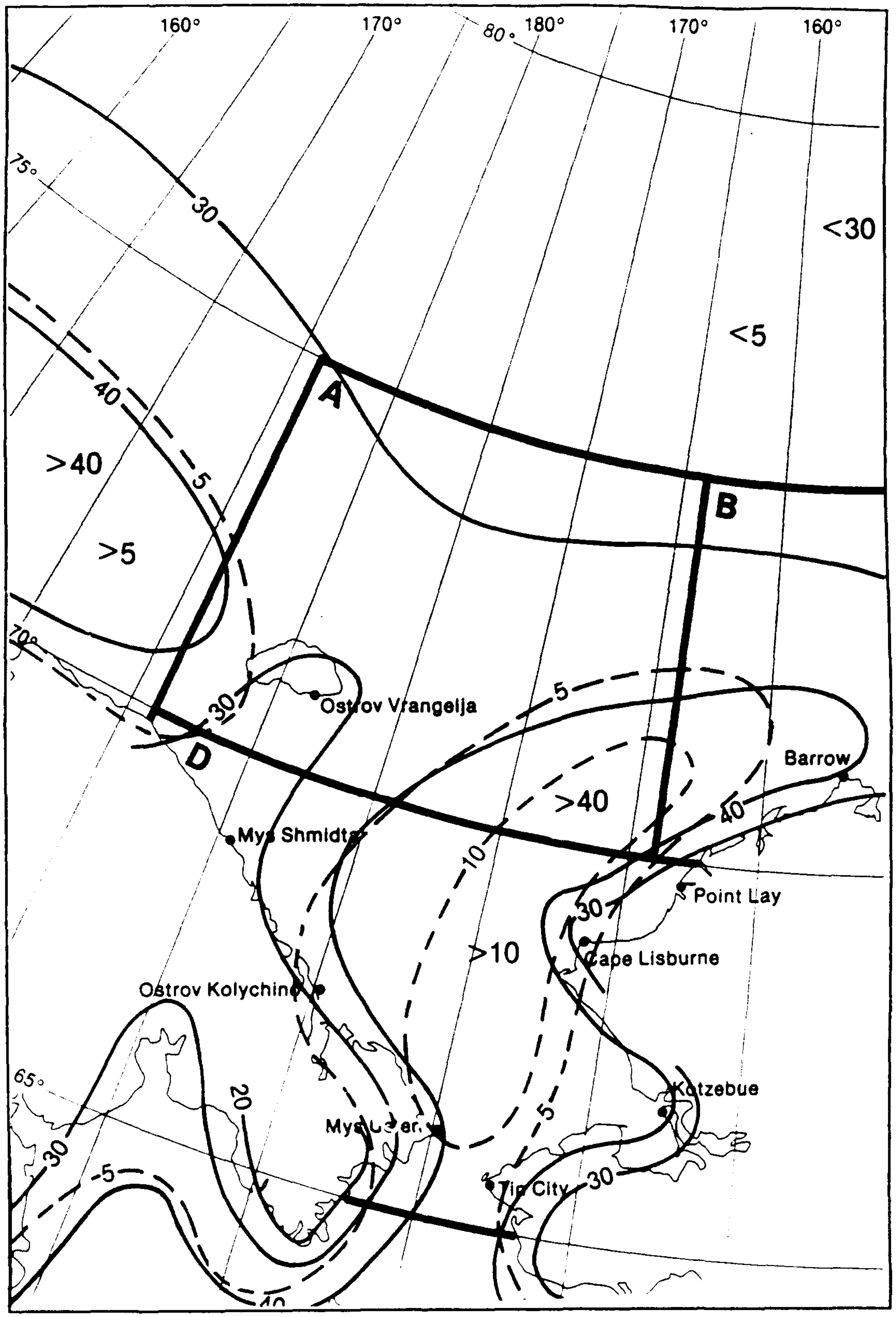
After Brower et al. 1988

Legend

———	% of Wind 11-21 Knots
— — —	% of Wind 22-33 Knots

Figure 27f

Wind Speed 11-21 and 22-33 Knots



July

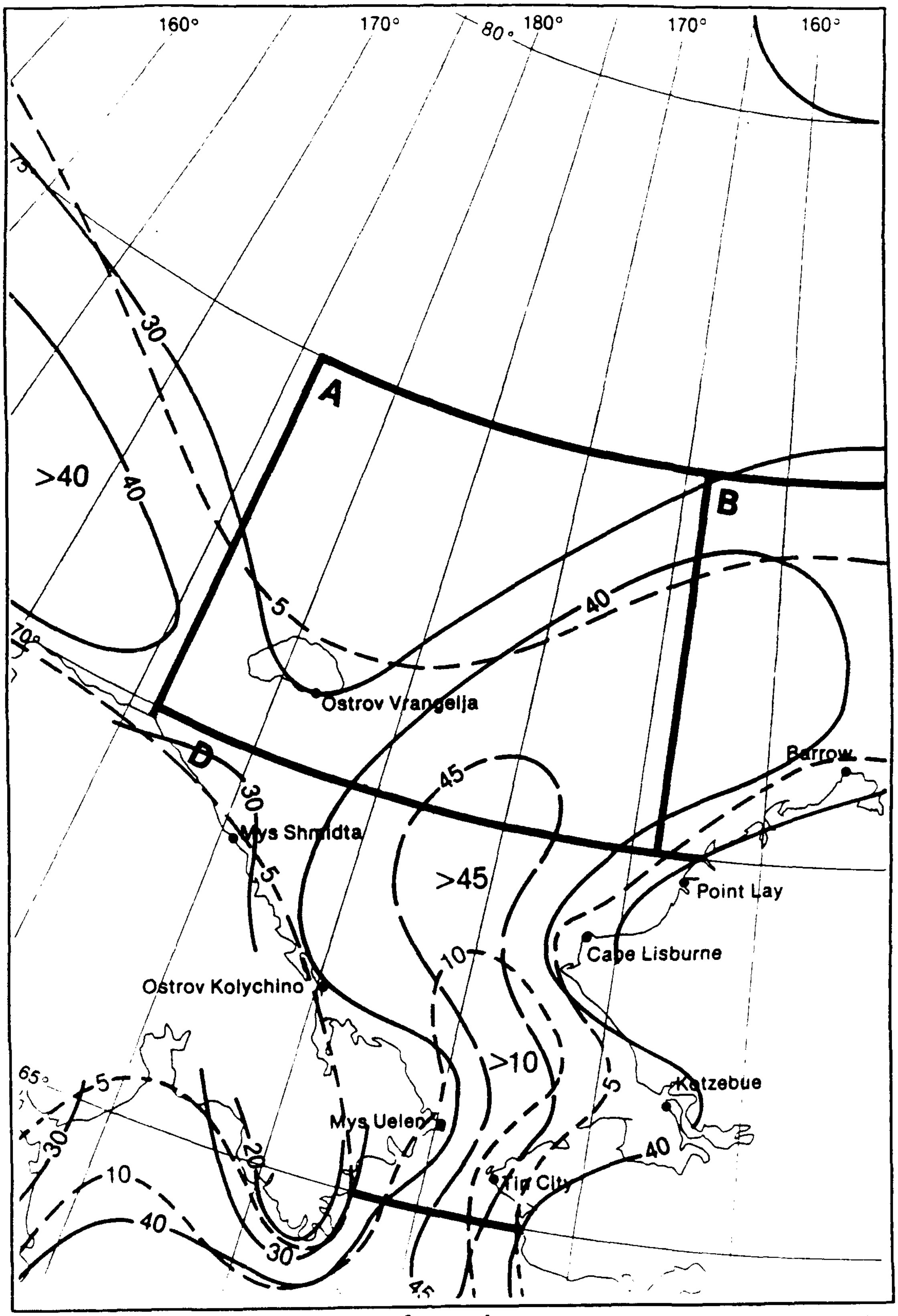
After Brower et al. 1988

Legend

% of Wind 11-21 Knots
% of Wind 22-33 Knots

Figure 27g

Wind Speed 11-21 and 22-33 Knots



August

After Brower et al. 1988

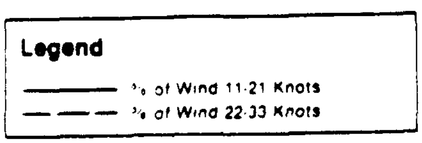
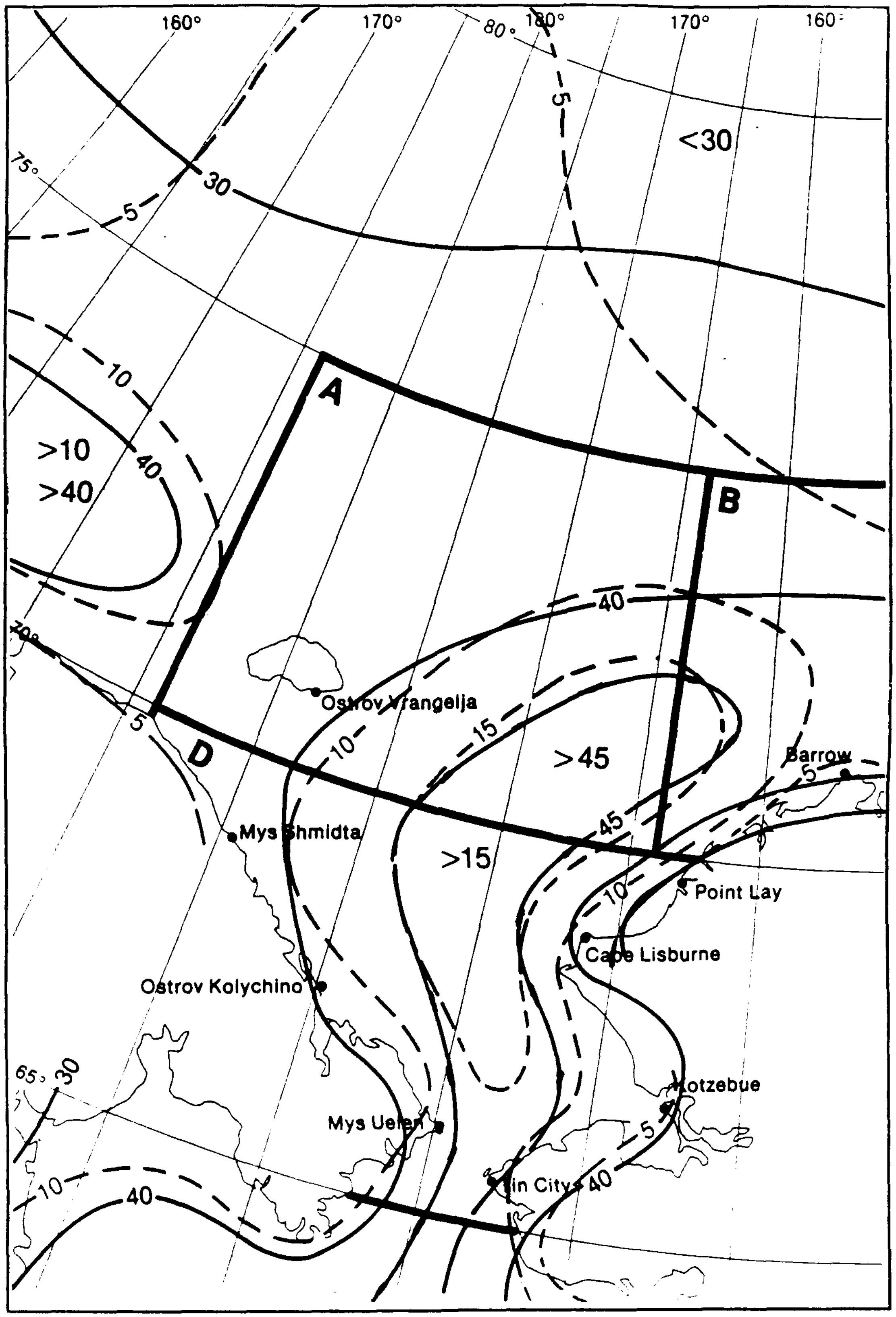


Figure 27h

Wind Speed 11-21 and 22-33 Knots



September

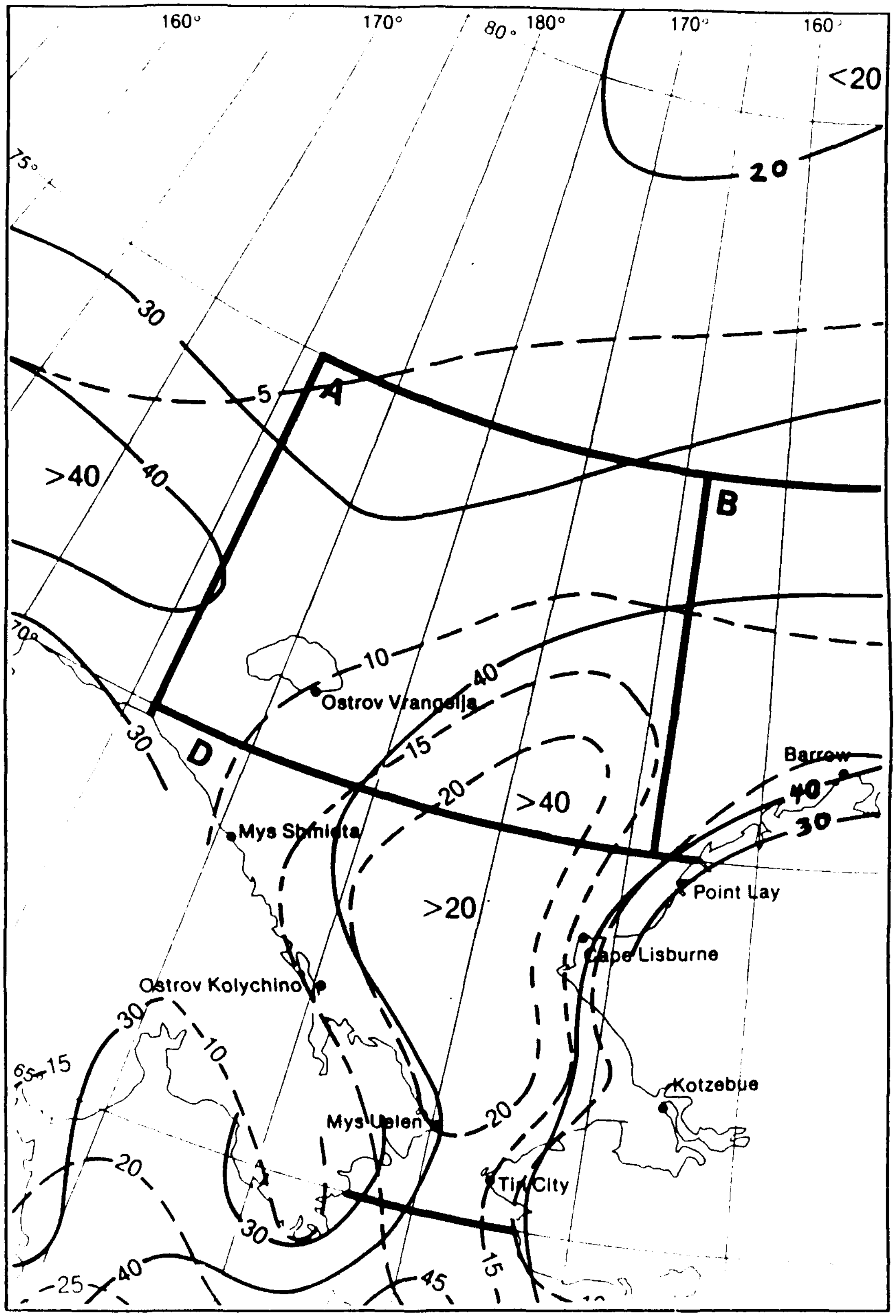
After Brower et al. 1988

Legend

——— ⅔ of Wind 11-21 Knots
— — — ⅔ of Wind 22-33 Knots

Figure 27i

Wind Speed 11-21 and 22-33 Knots



October

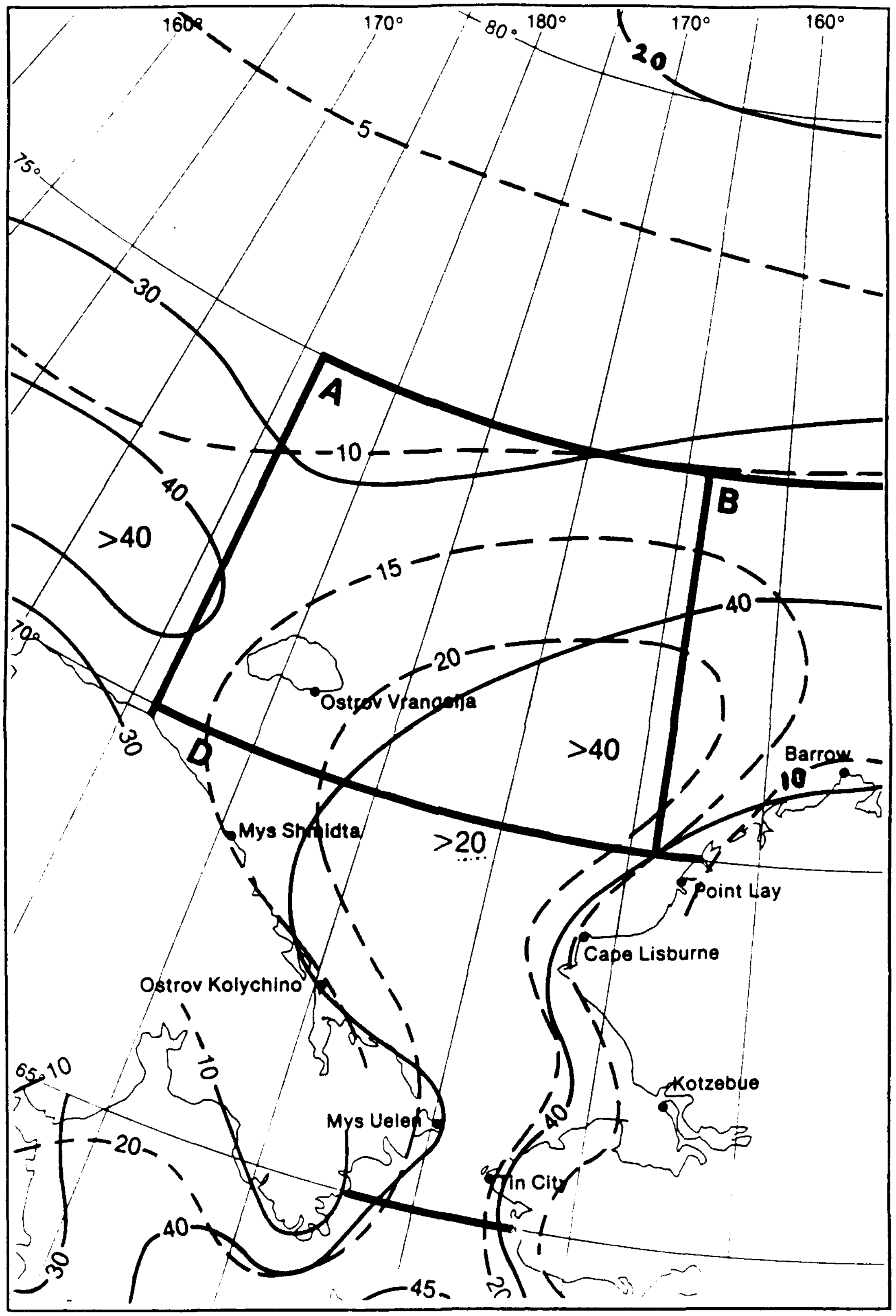
After Brower et al. 1988

Legend

—— % of Wind 11-21 Knots
– – – % of Wind 22-33 Knots

Figure 27j

Wind Speed 11-21 and 22-33 Knots



November

After Brower et al. 1988

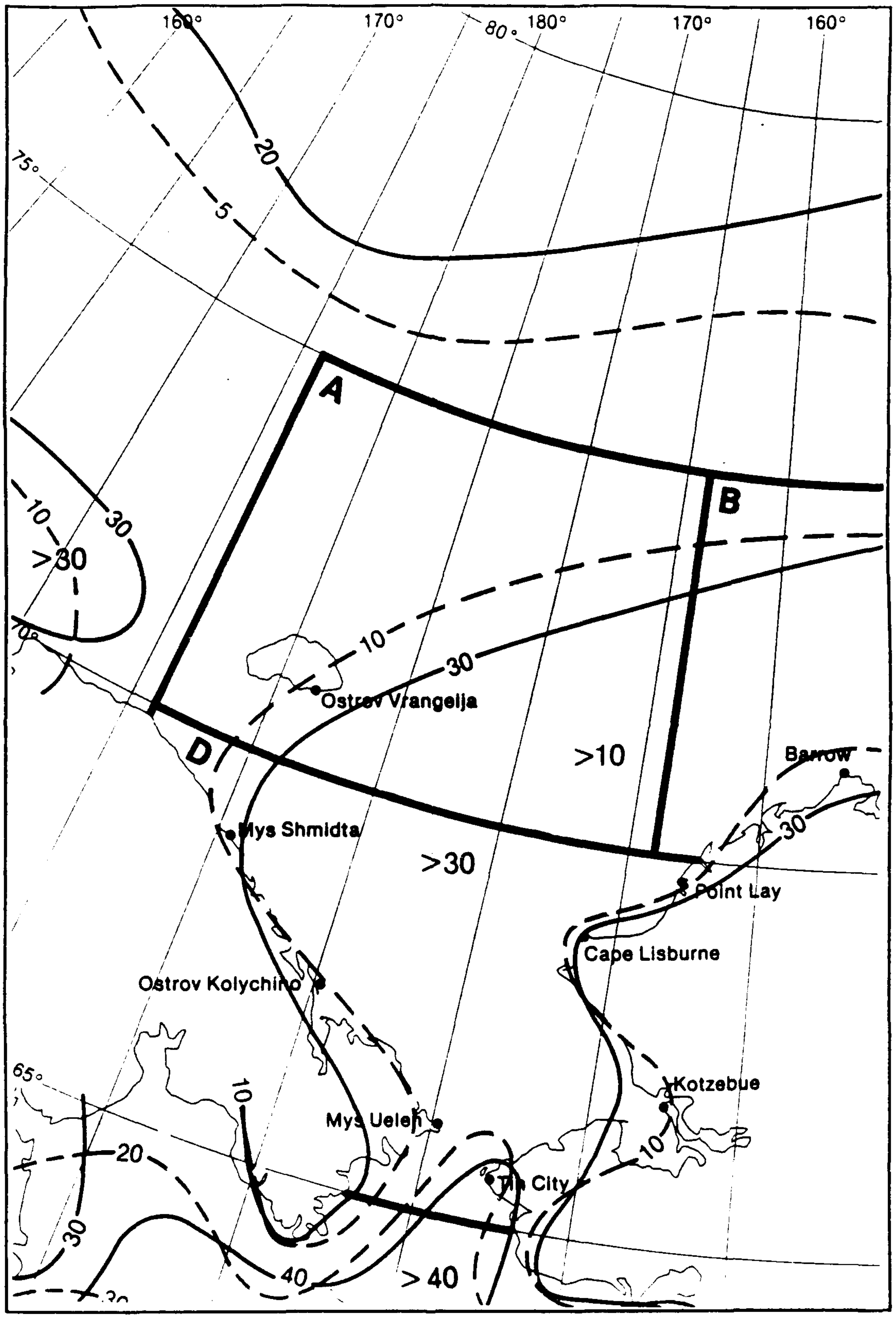
Legend

——— % of Wind 11-21 Knots

— — — % of Wind 22-33 Knots

Figure 27k

Wind Speed 11-21 and 22-33 Knots



December

After Brower et al. 1988

Legend

———— % of Wind 11-21 Knots

— — — — % of Wind 22-33 Knots

Figure 271

PRECIPITATION

Total precipitation is actually quite light in the Chukchi Sea area. Table 3 showed a range for total annual precipitation from 12.08 inches in Tin City to 4.75 inches in Point Barrow. Most of this precipitation falls in the "summer" months from June through October. Low temperatures are the primary reason for low total precipitation. Cold temperatures lower the absolute humidity and decrease the amount of available moisture. Thus, most of the precipitation falls as light rain during the warmer summer.

Figures 28a-28l show the percent frequency of different types of precipitation in the three marine areas and at nine land stations.

Graphs: Precipitation types

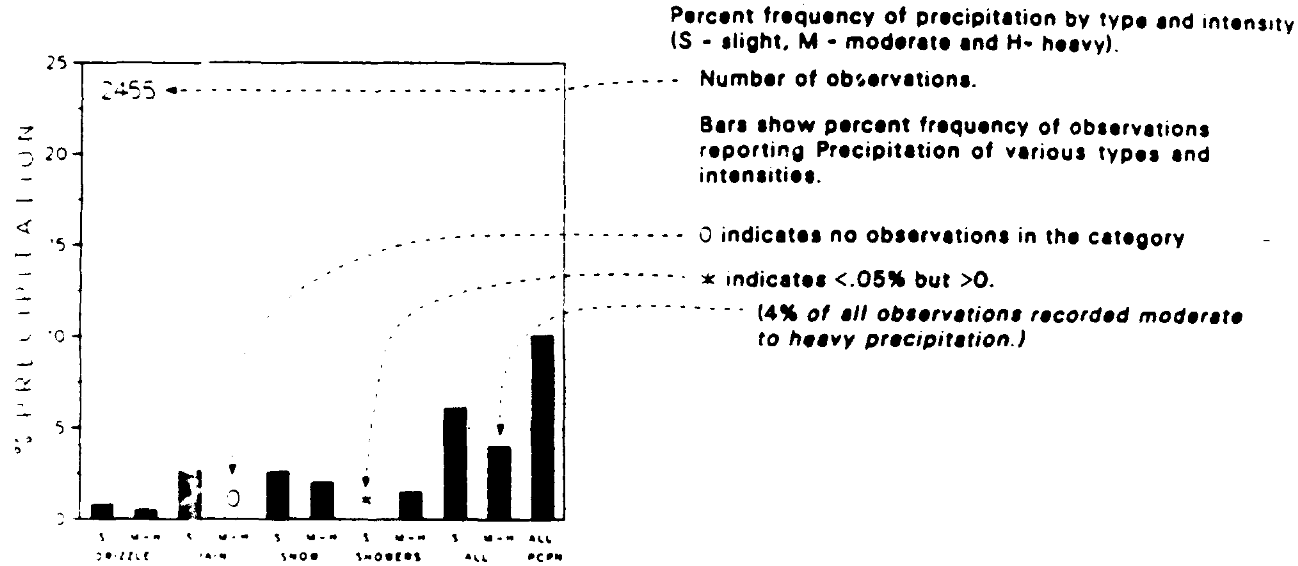
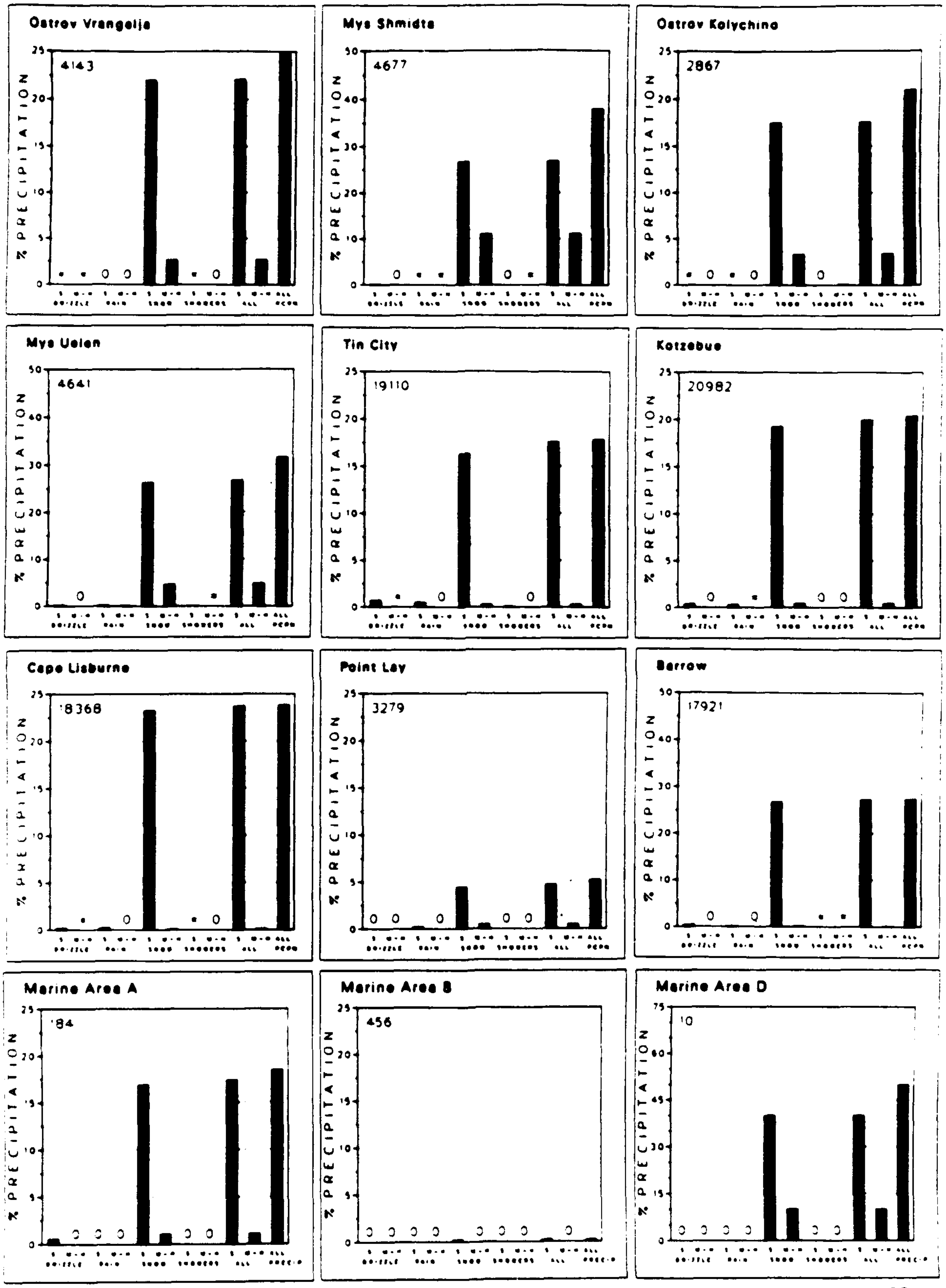


Figure 28

Precipitation Types

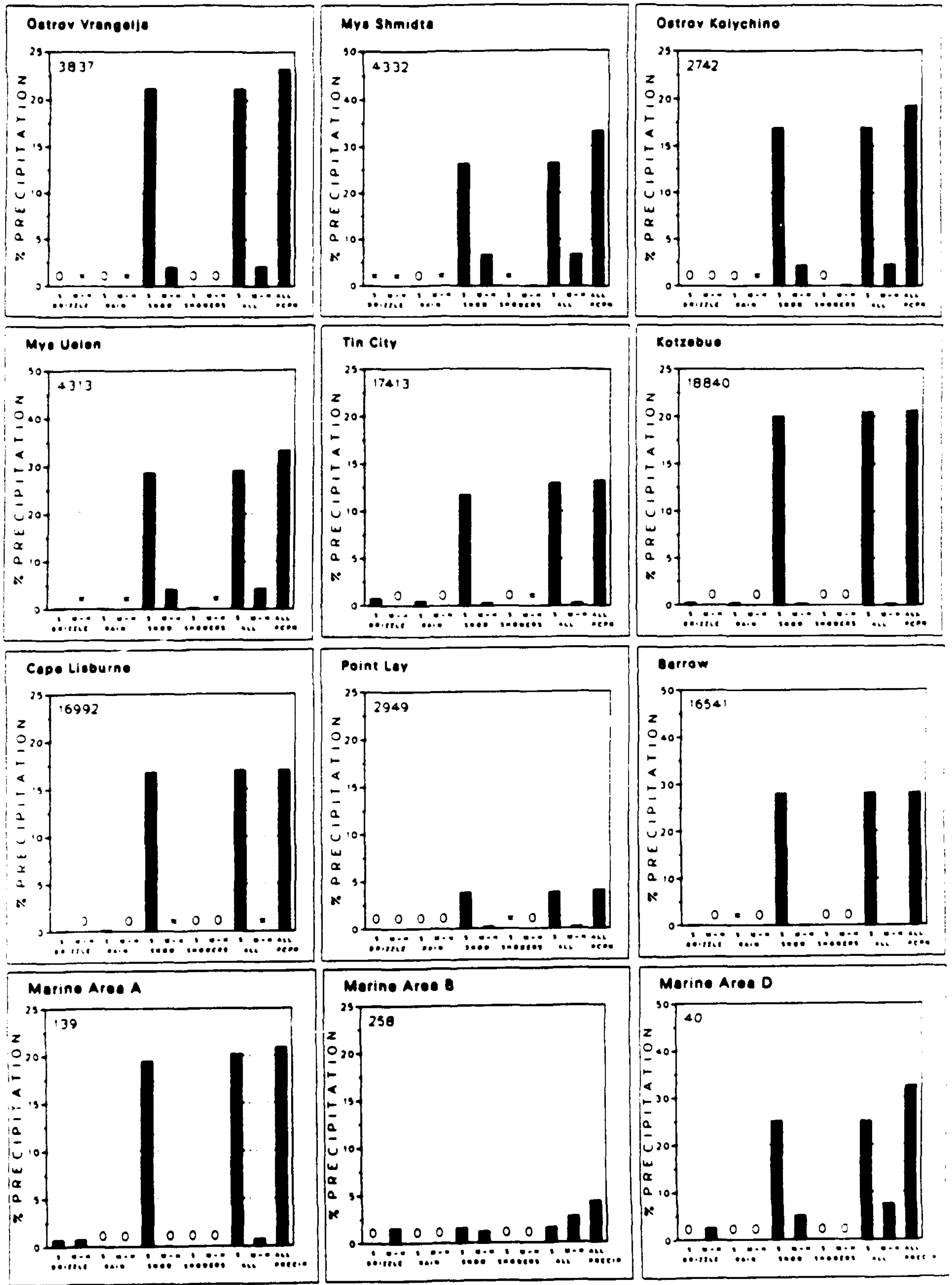


January

After Brower et al. 1988

Figure 28a

Precipitation Types

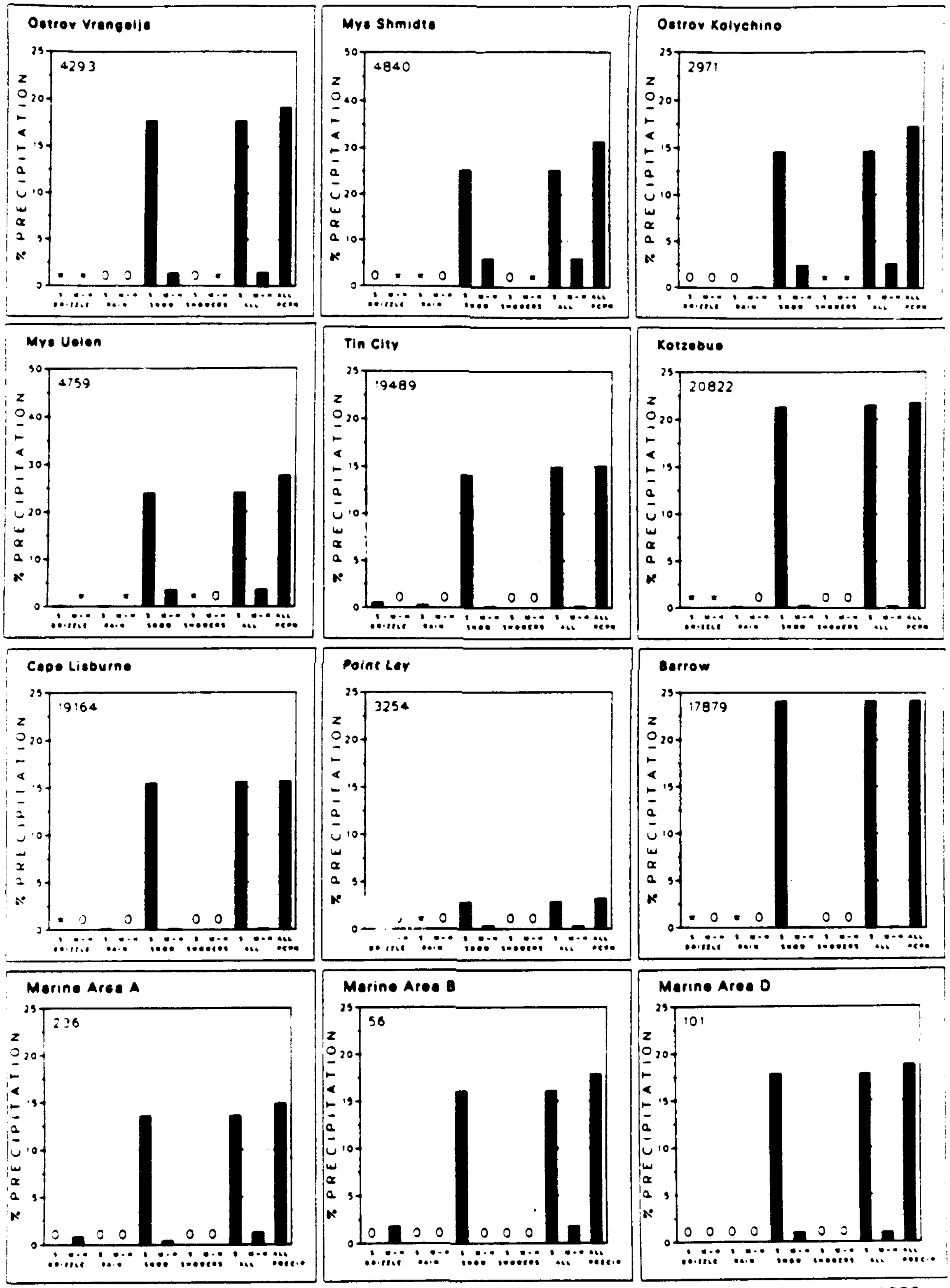


February

After Brower et al. 1988

Figure 28b

Precipitation Types

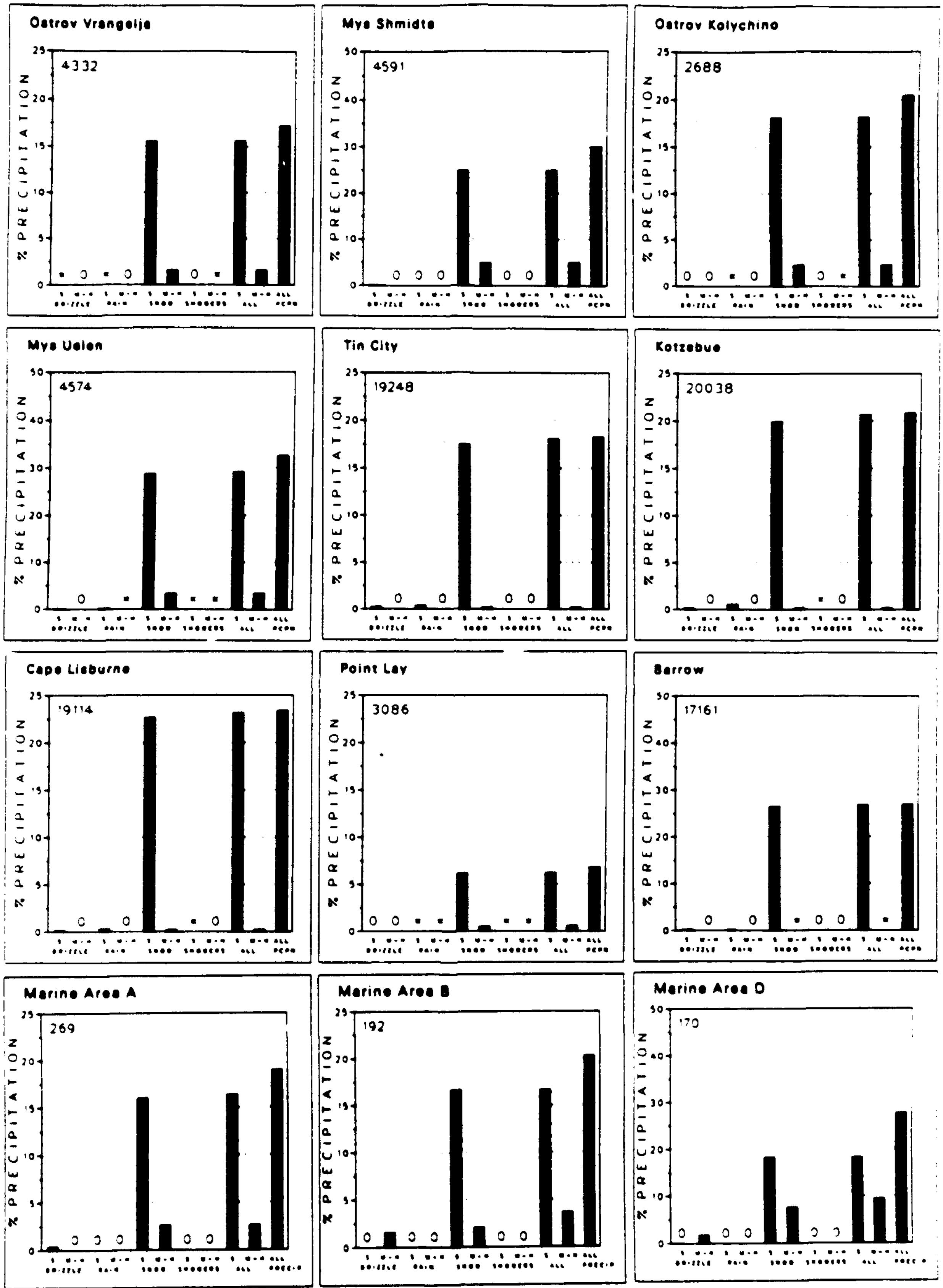


March

After Brower et al. 1988

Figure 28c

Precipitation Types

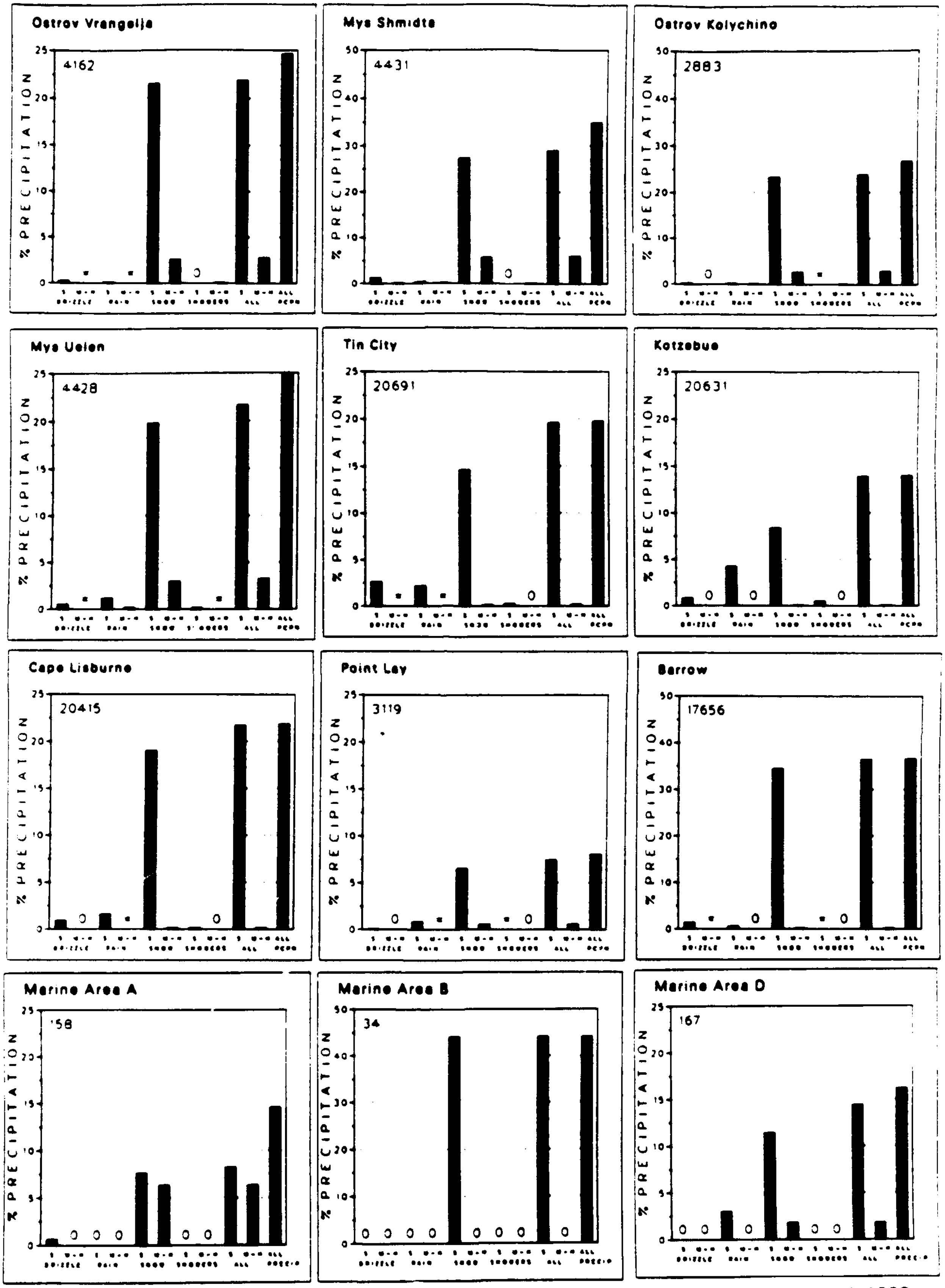


April

After Brower et al. 1988

Figure 28d

Precipitation Types

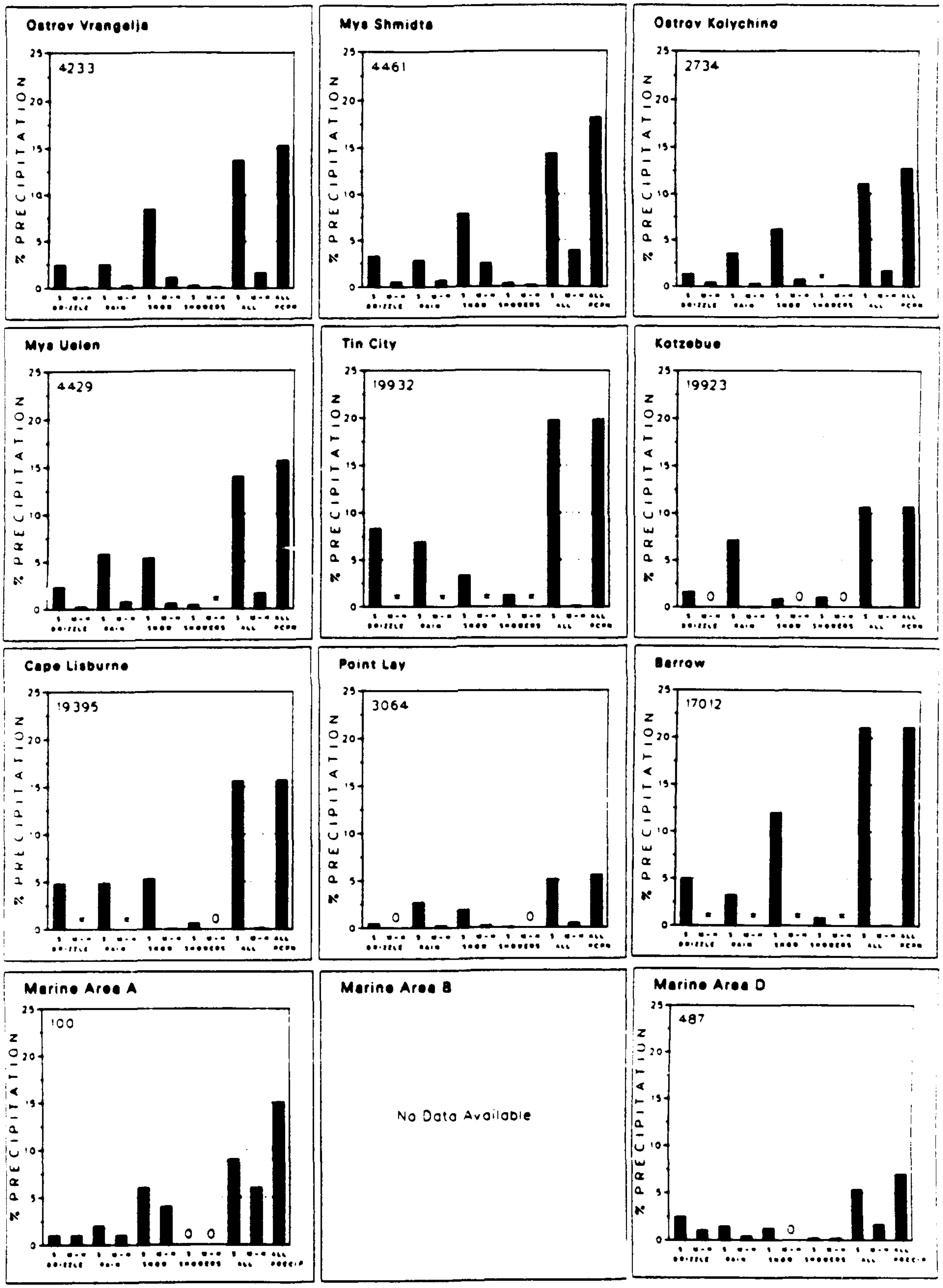


May

After Brower et al. 1988

Figure 28e

Precipitation Types

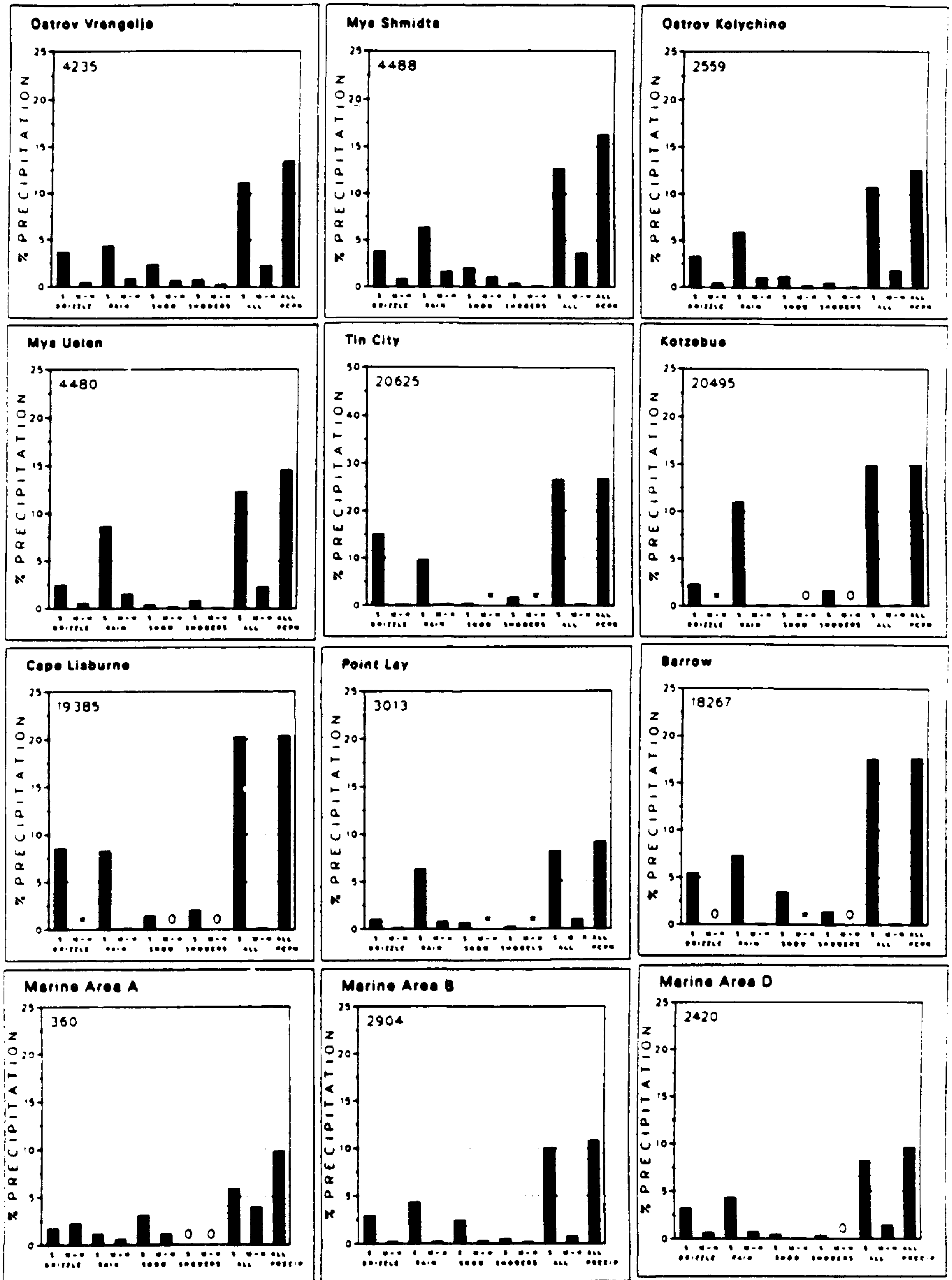


June

After Brower et al. 1988

Figure 28f

Precipitation Types

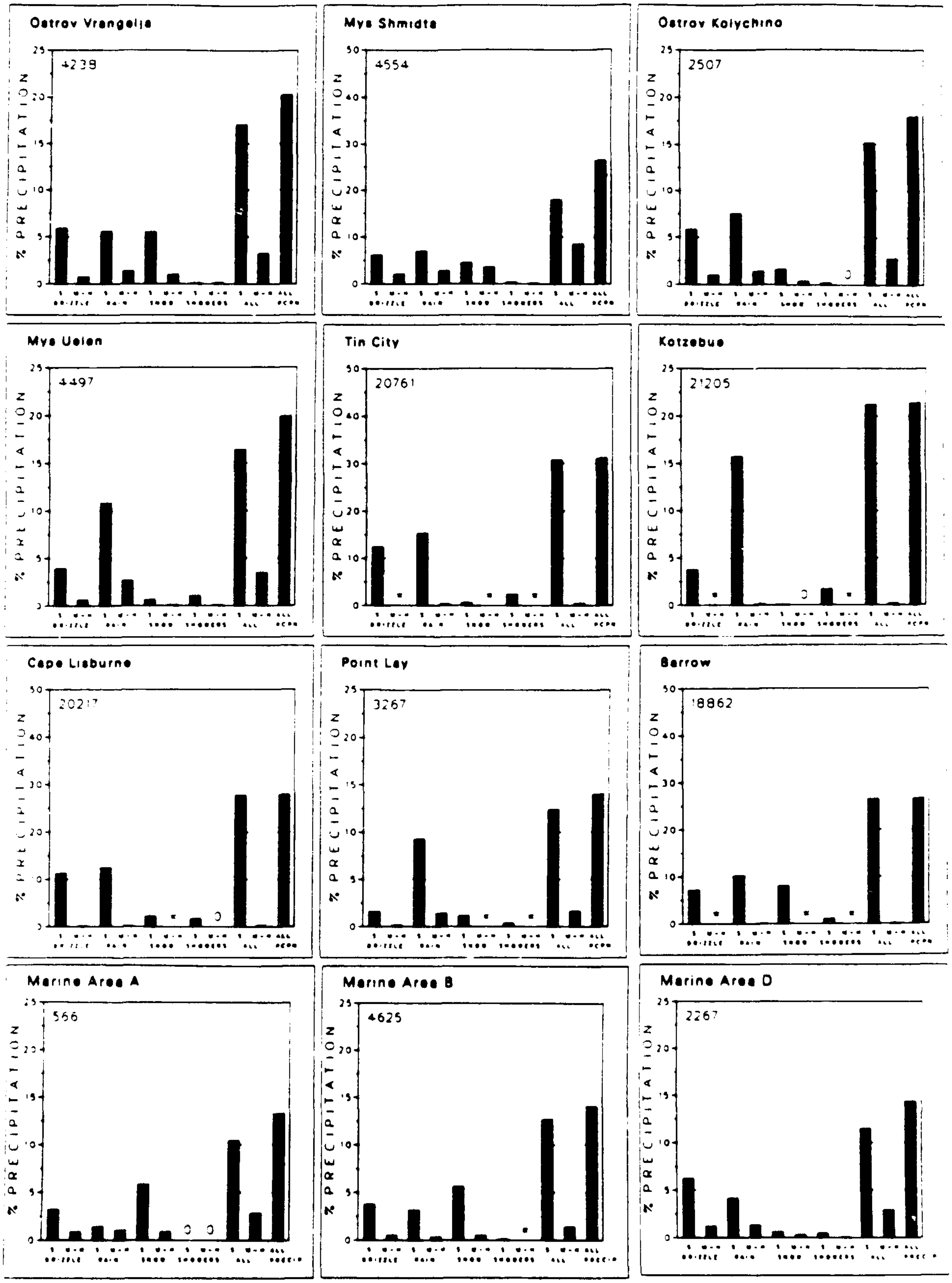


July

After Brower et al. 1988

Figure 28g

Precipitation Types

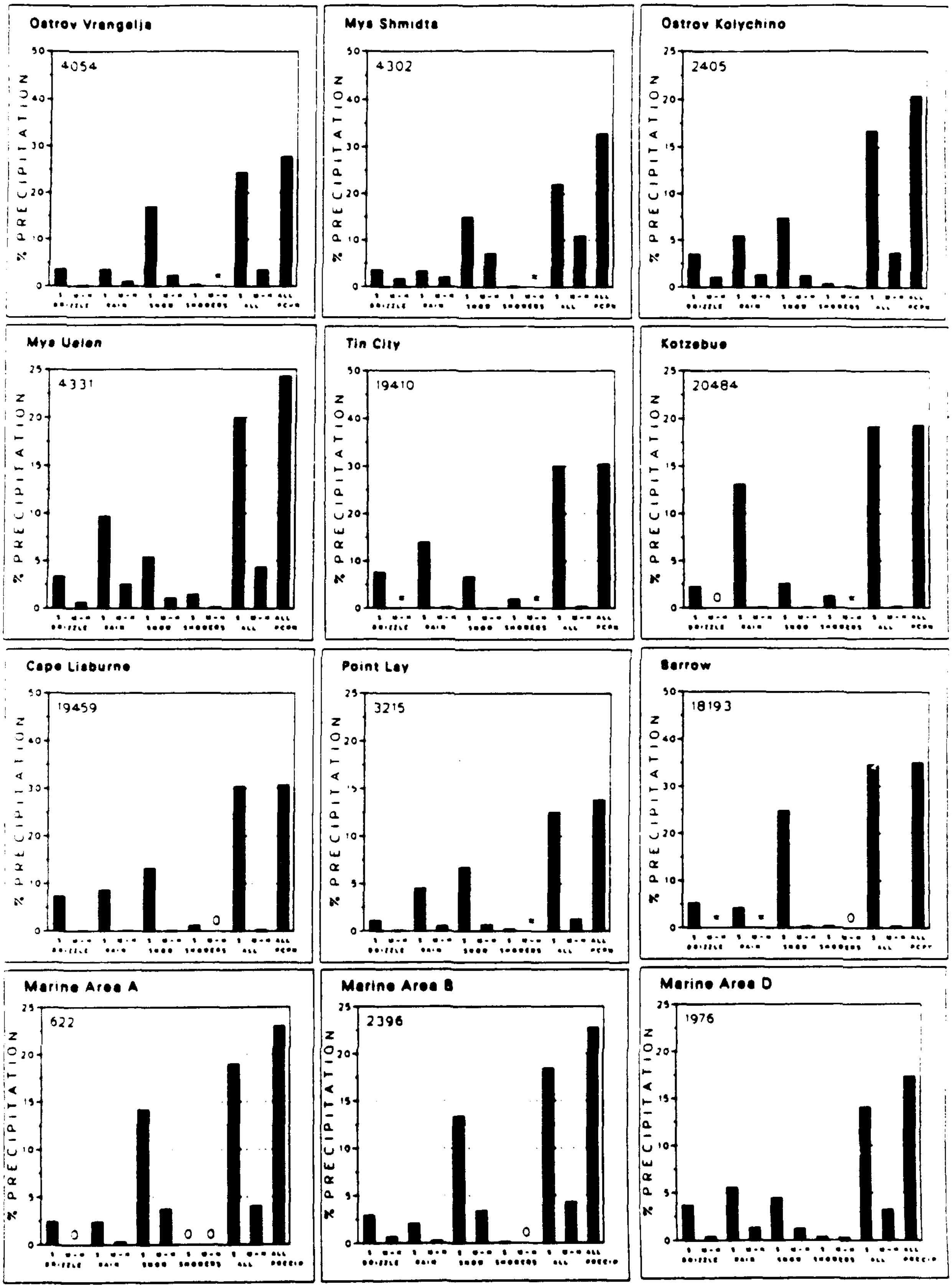


August

After Brower et al. 1988

Figure 28h

Precipitation Types

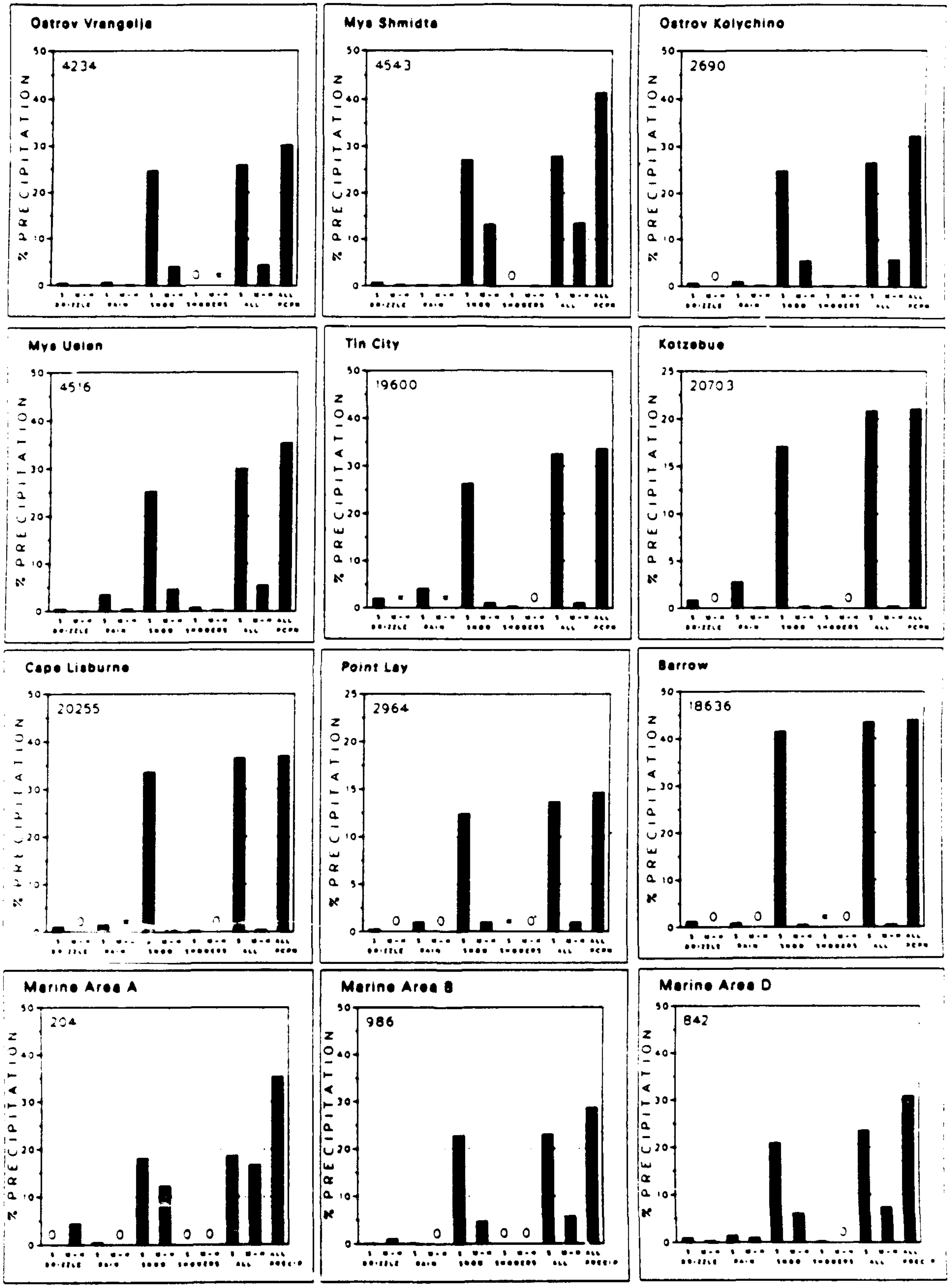


September

After Brower et al. 1988

Figure 28i

Precipitation Types

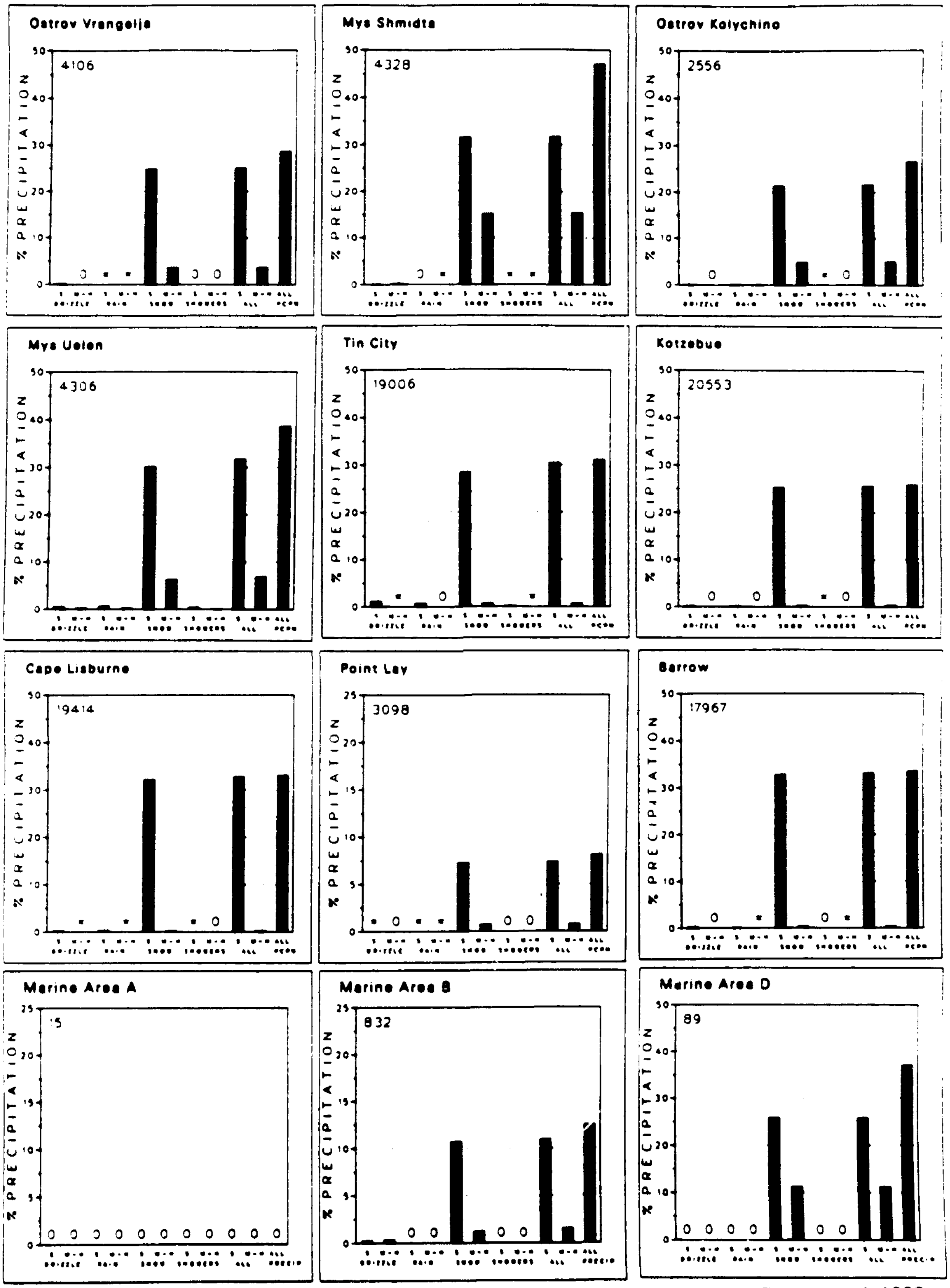


October

After Brower et al. 1988

Figure 28j

Precipitation Types

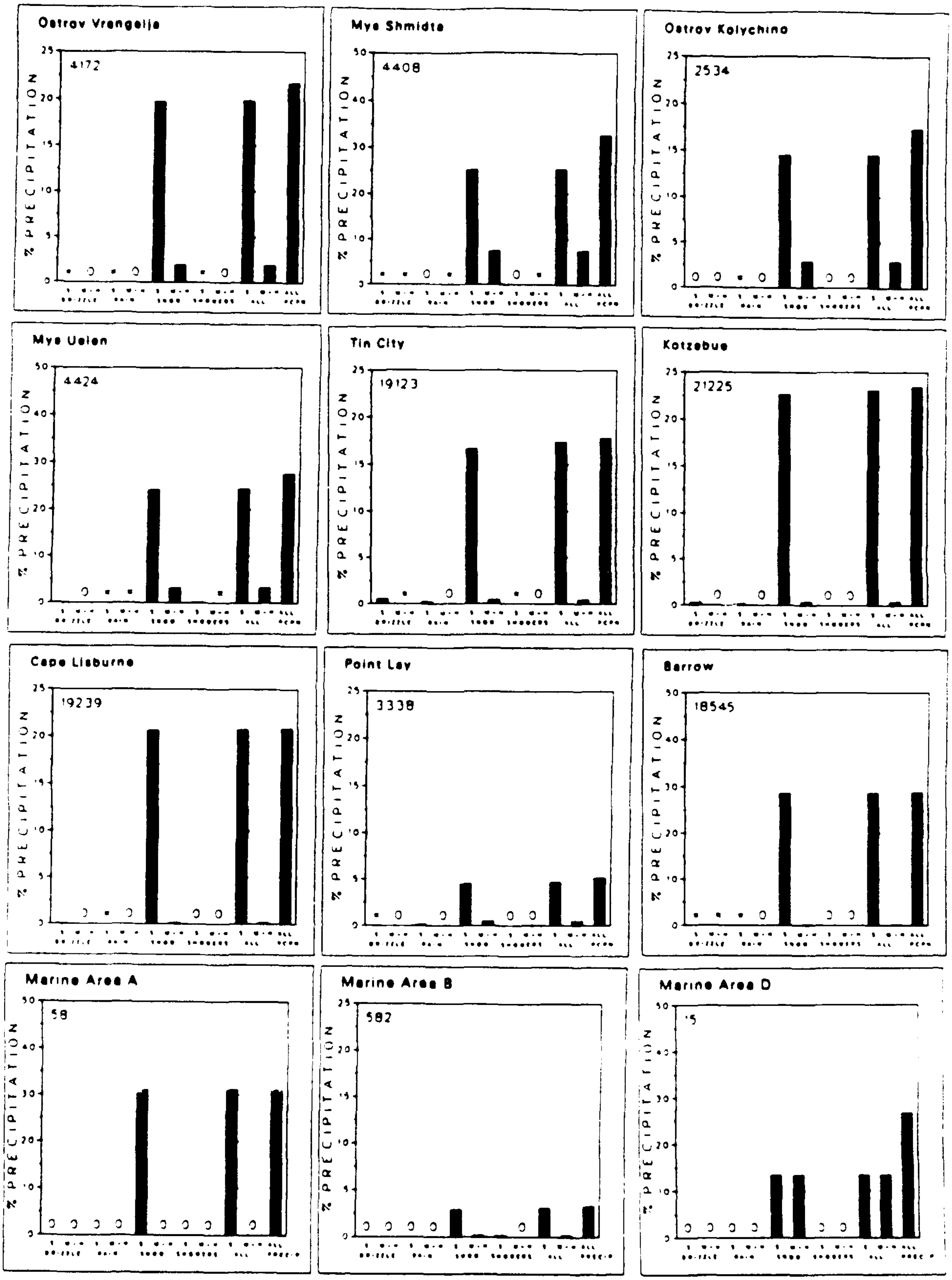


November

After Brower et al. 1988

Figure 28k

Precipitation Types



December

After Brower et al. 1988

Figure 28l

VISIBILITY

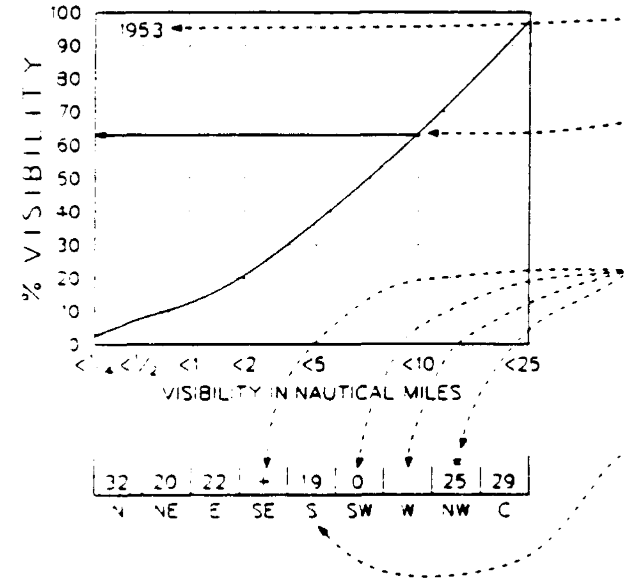
Low-stratus clouds and advection fog are relatively common in the warmer months because of the passage of warmer air masses over the cold ice surfaces. For instance, Point Barrow averages less than 4 days of fog per month except for May, June, July, August and September when there are 8, 13, 13, 11, and 5 days of fog respectively. During winter visibility can be limited by a combination of short solar day, low sun angle, very light snowfall, occasional wind-blown snow, and a low clinging fog which is often observed over leads and other open water areas. Air over open water in cold winter conditions becomes saturated almost immediately because of low water-vapor capacity of cold air.

Figures 29a-29l show the visibility coincidental with different wind directions.

Figures 30a-30l indicates the occurrence of fog versus different wind directions and time periods during the day.

Figures 31a-31l charts the incidence of fog at various air-sea temperature differences.

Graphs: Visibility/wind direction



Number of observations.

Curve is the cumulative percent frequency of visibilities less than the visibility intersected by the curve.

(63% of all visibilities reported were <10 nautical miles.)

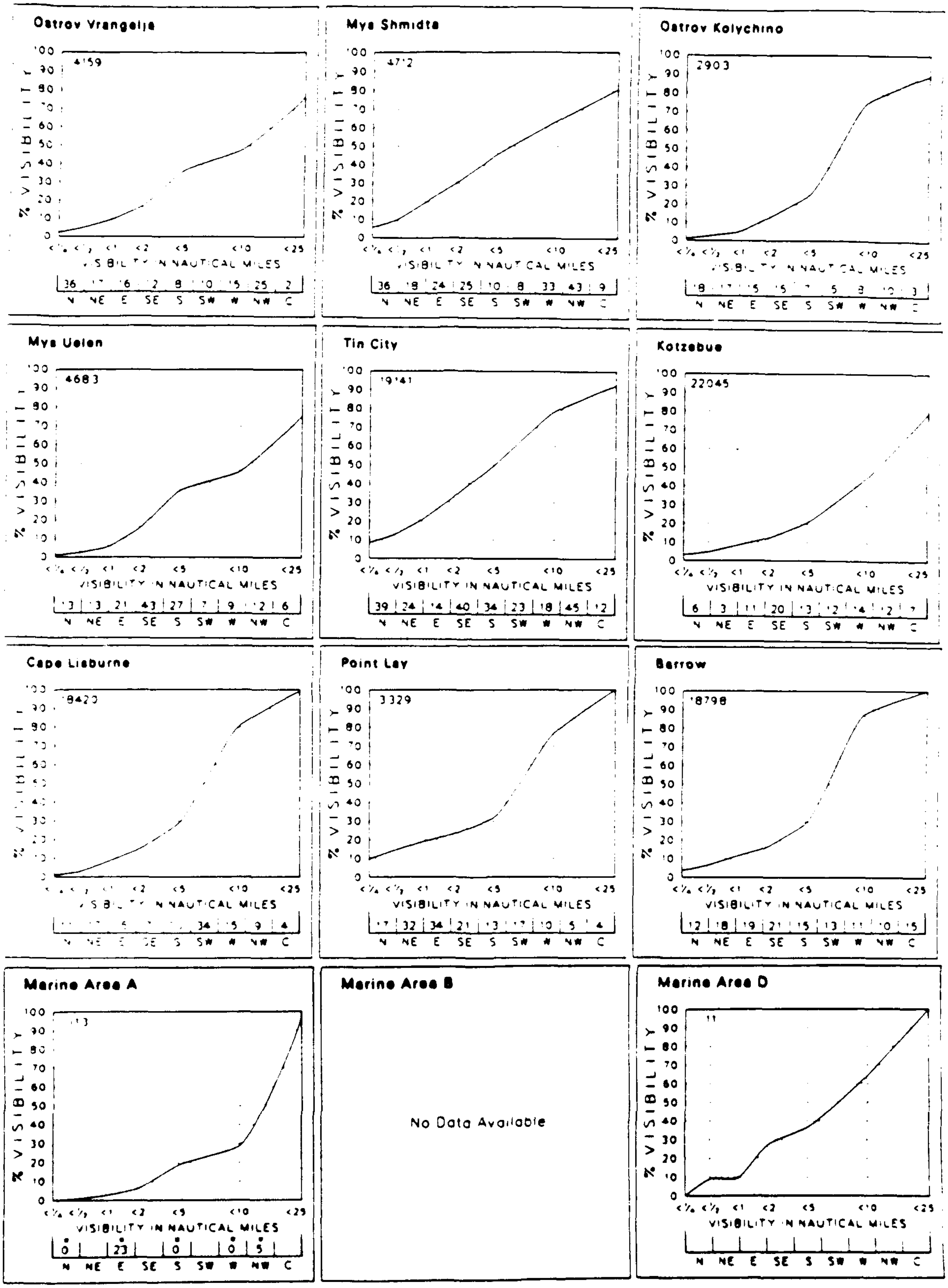
The table below the graph indicates percent frequency of occurrence of visibility <2 nautical miles versus wind direction.

+ indicates <.5% but >0. 0 indicates that no visibilities <2 nautical miles were observed with winds from a direction or calm. No percentage is given if less than 10 observations were available for visibility and wind direction. An asterisk indicates that the percentage was based on 10-30 observations of visibility and wind direction.

(19% of all S winds were accompanied by visibilities <2 nautical miles.)

Figure 29

Visibility/Wind Direction

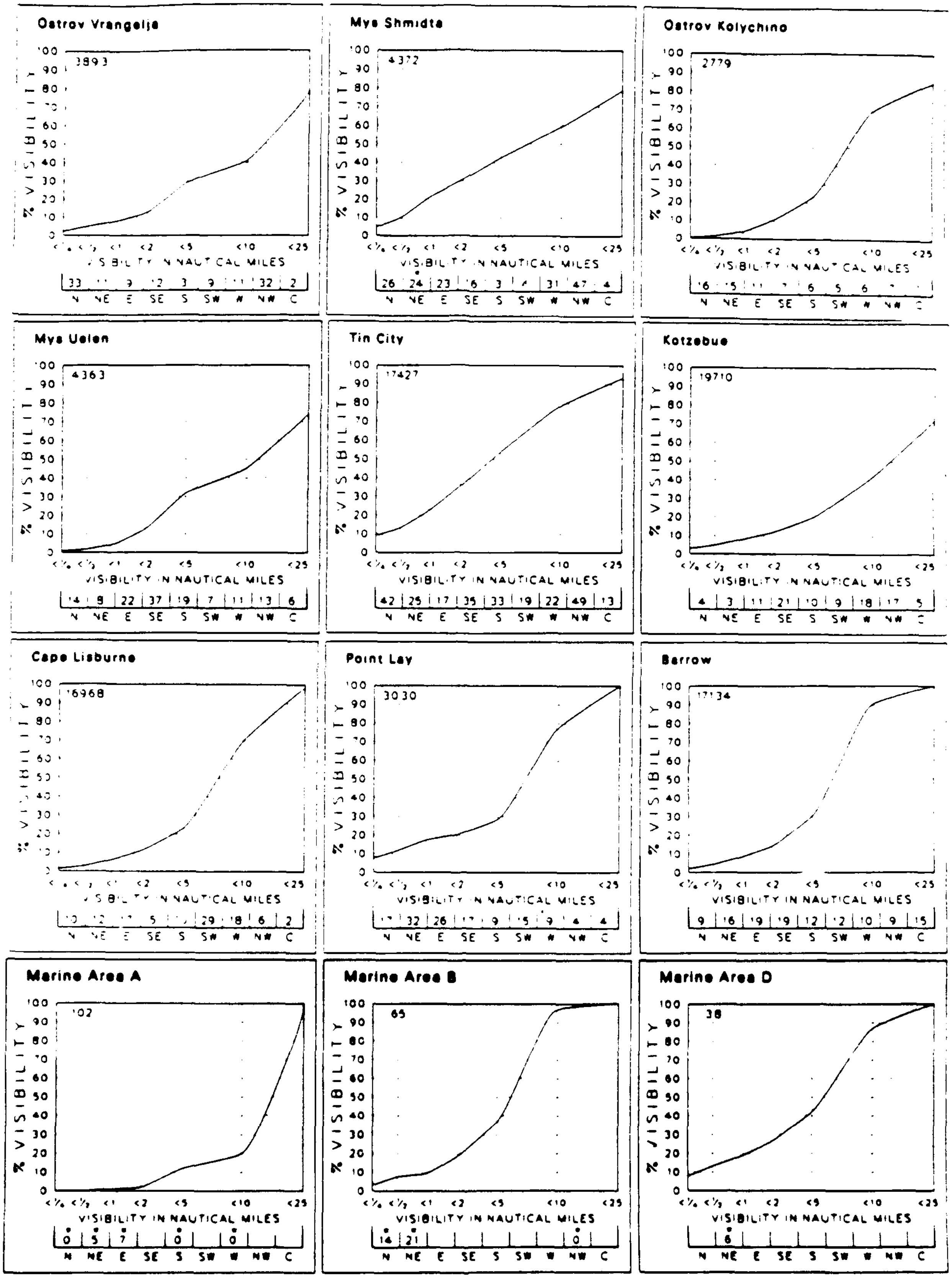


January

After Brower et al. 1988

Figure 29a

Visibility/Wind Direction

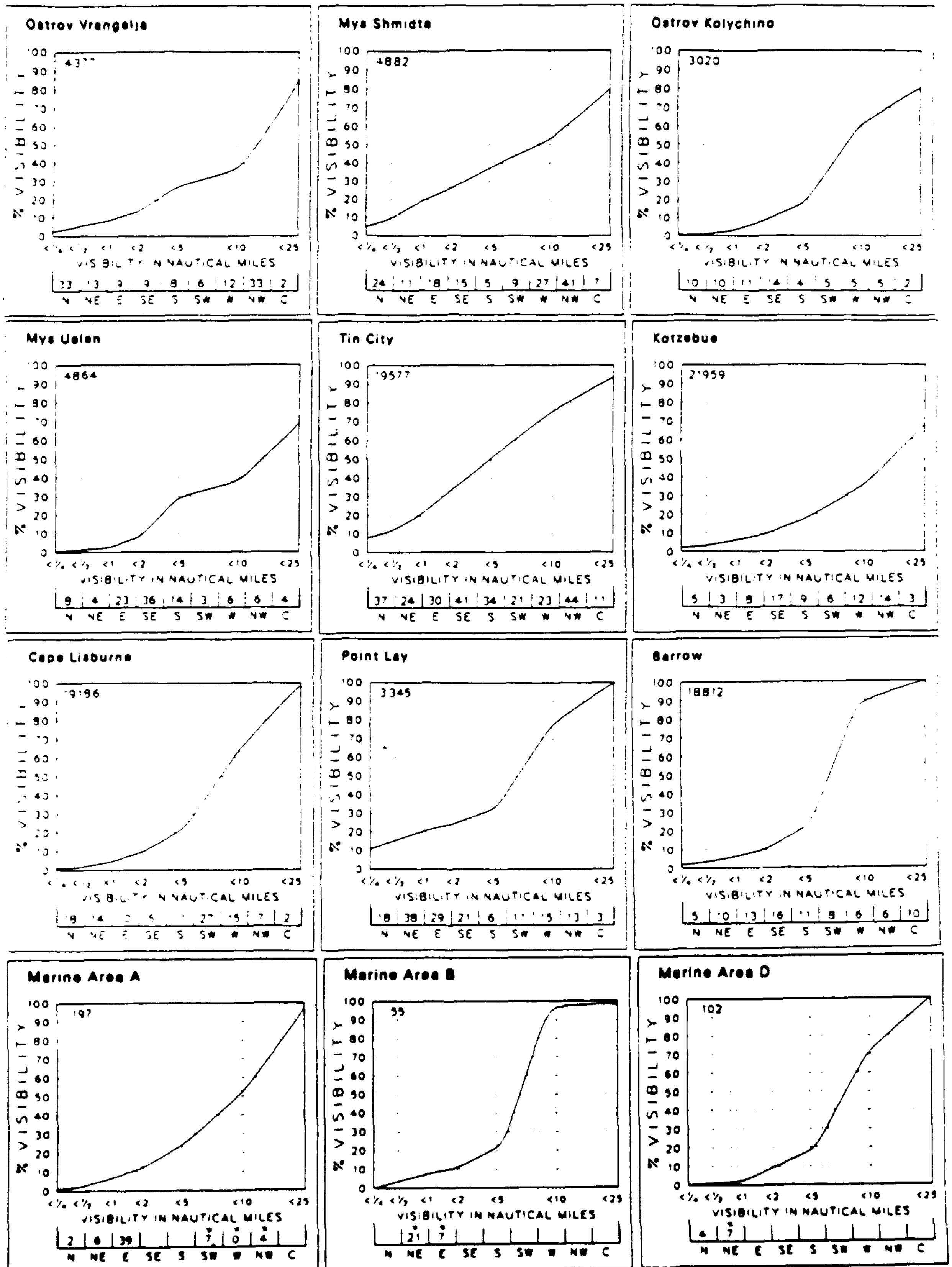


February

After Brower et al. 1988

Figure 29b

Visibility/Wind Direction

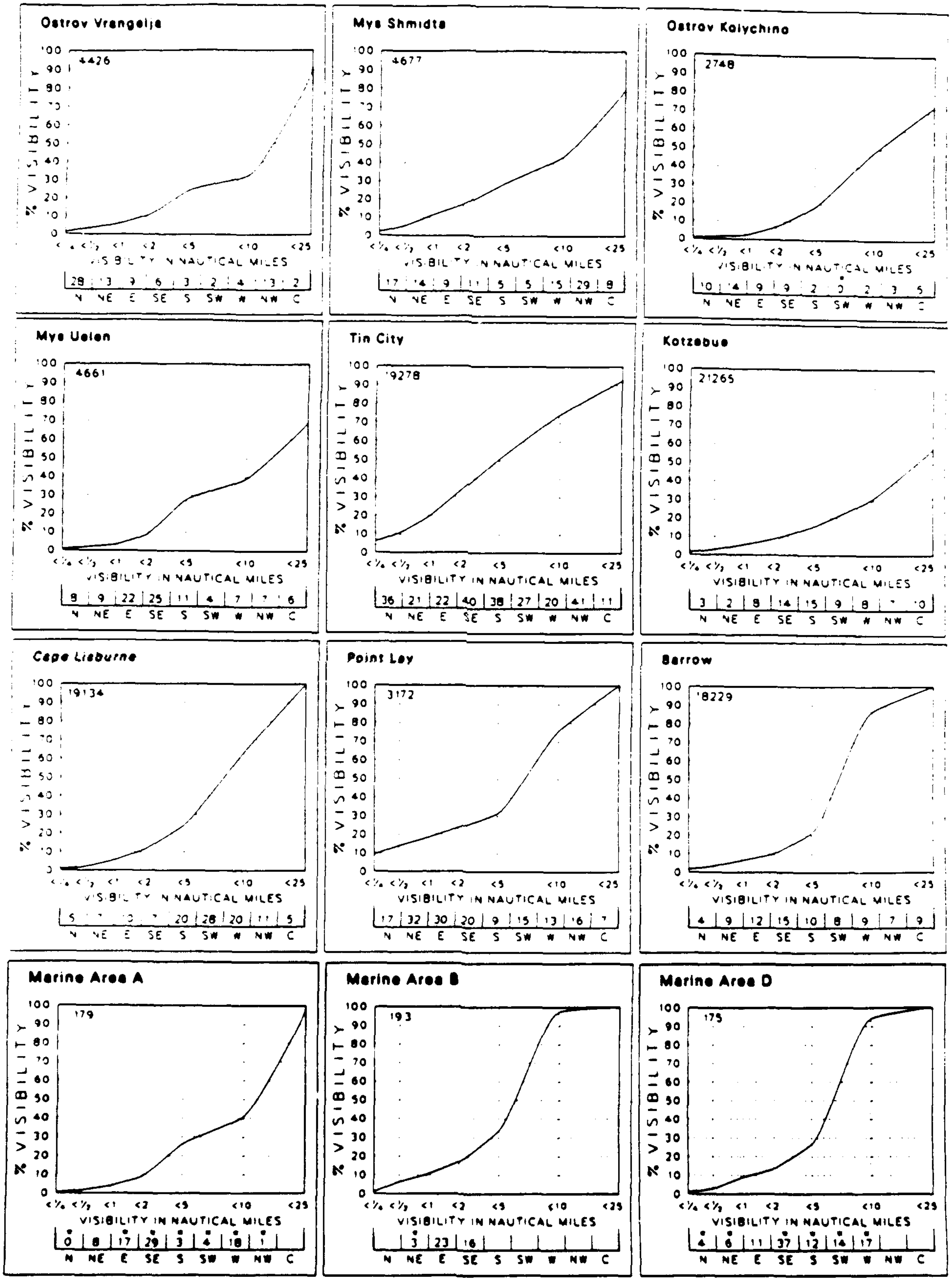


March

After Brower et al. 1988

Figure 29c

Visibility/Wind Direction

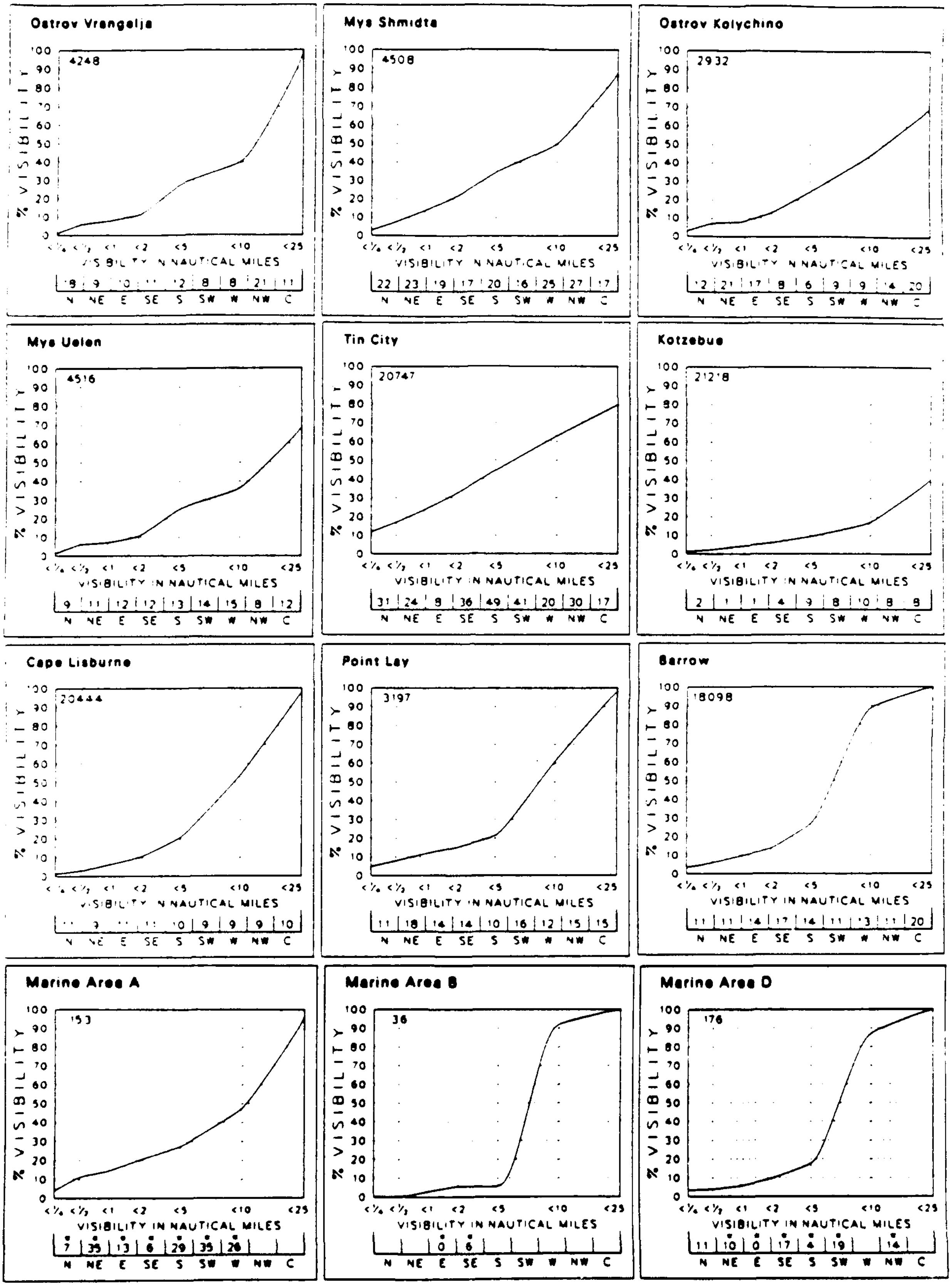


April

After Brower et al. 1988

Figure 29d

Visibility/Wind Direction

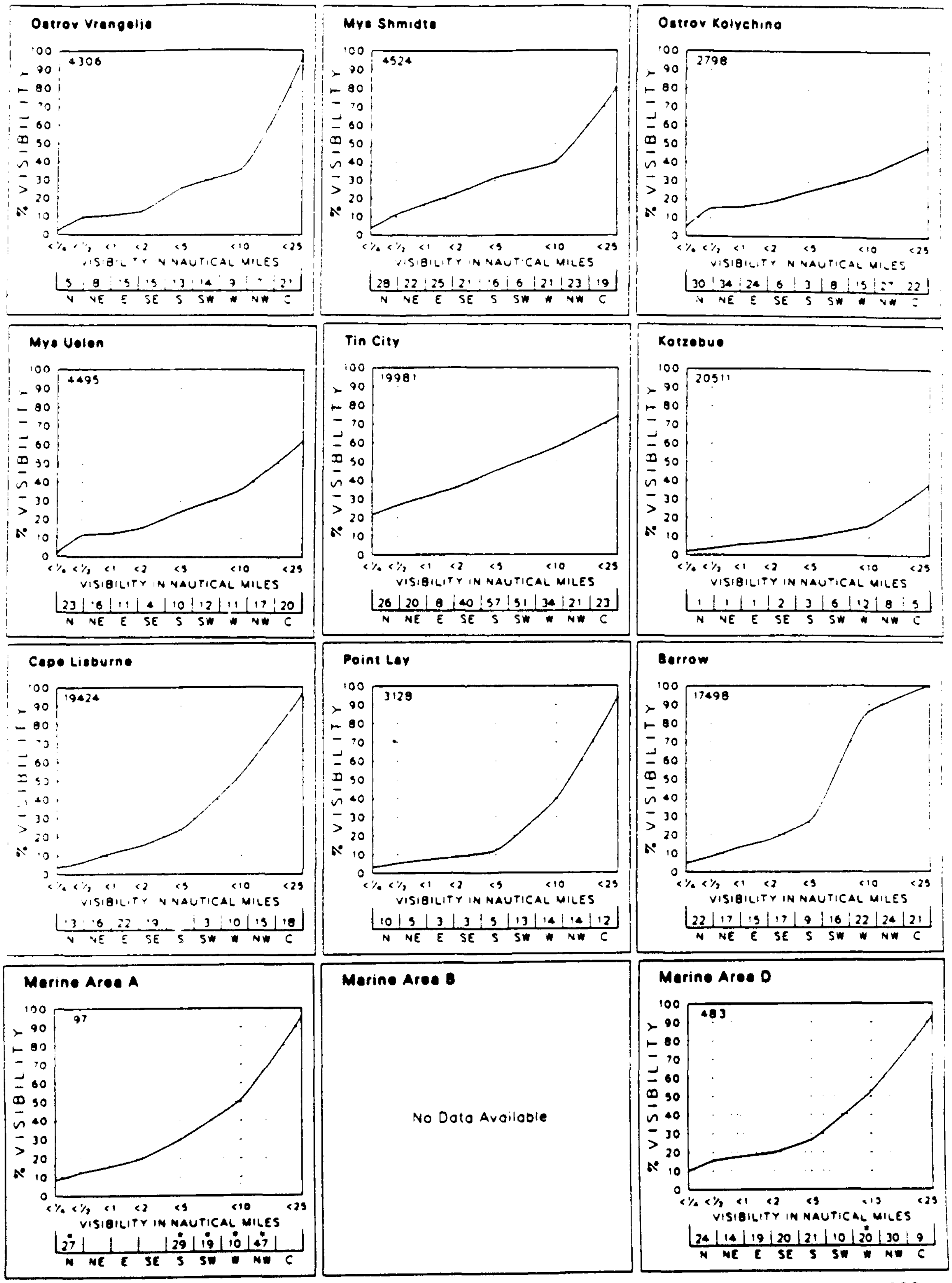


May

After Brower et al. 1988

Figure 29e

Visibility/Wind Direction

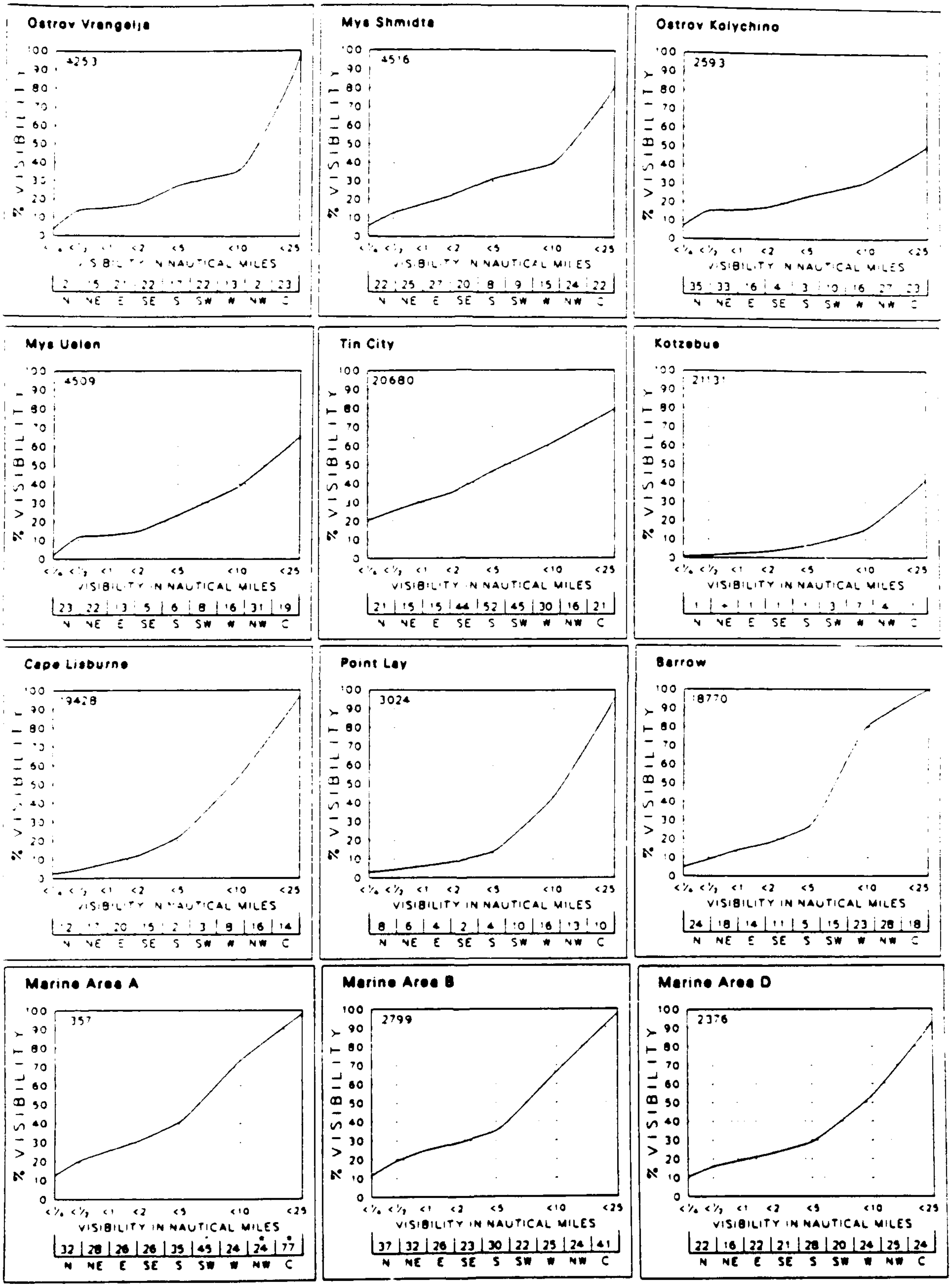


June

After Brower et al. 1988

Figure 29f

Visibility/Wind Direction

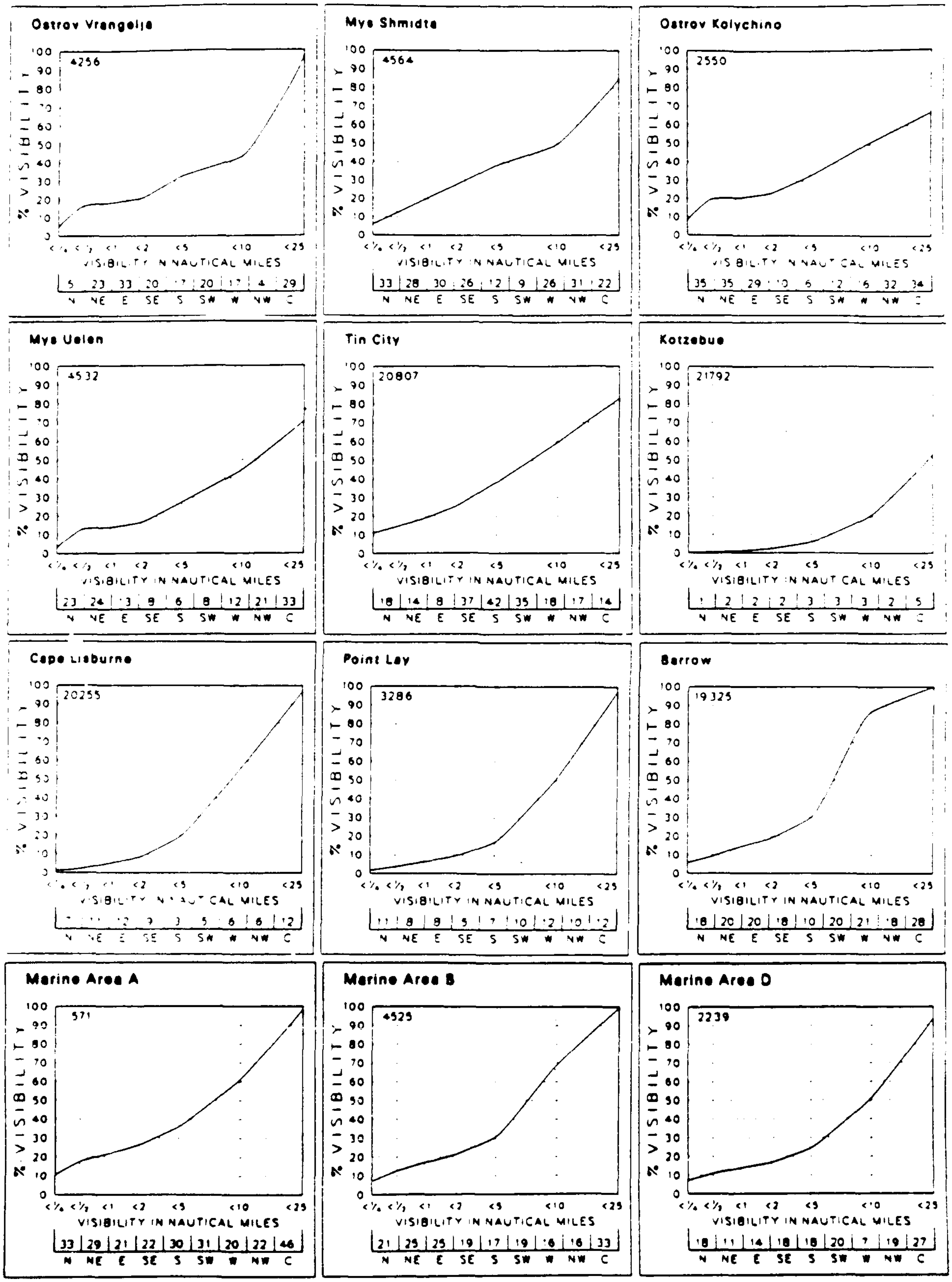


July

After Brower et al. 1988

Figure 29g

Visibility/Wind Direction

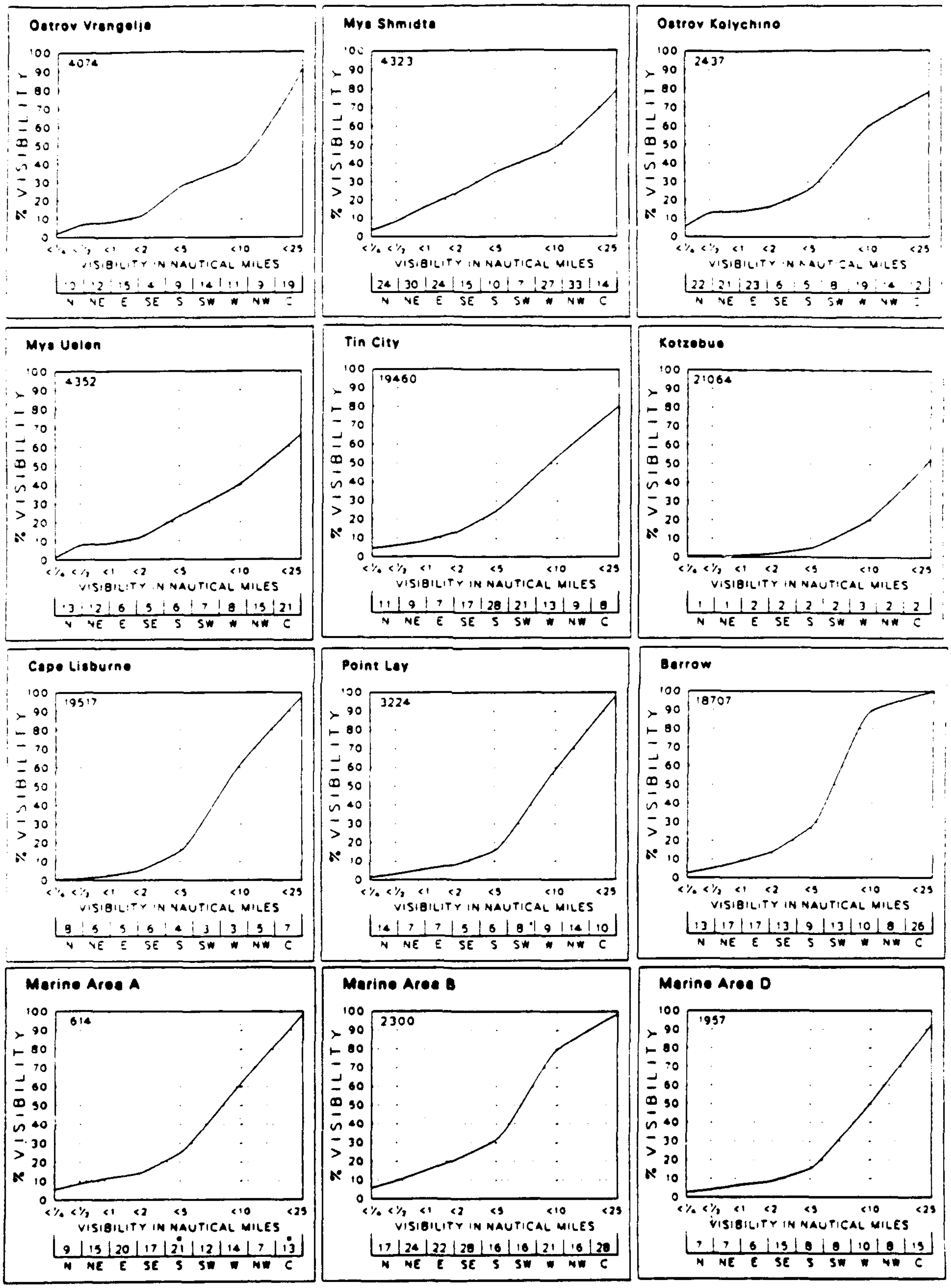


August

After Brower et al. 1988

Figure 29h

Visibility/Wind Direction

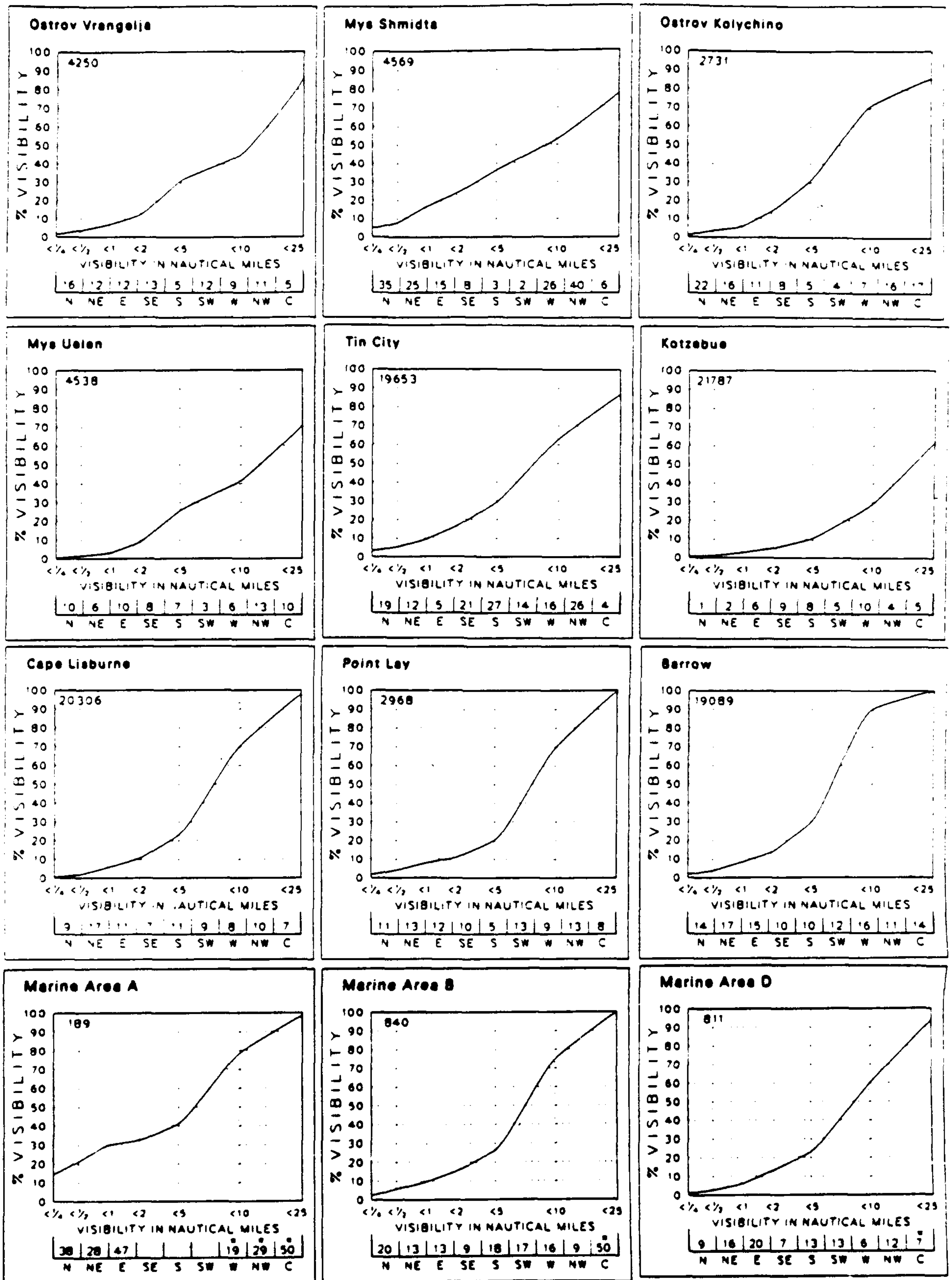


September

After Brower et al. 1988

Figure 29i

Visibility/Wind Direction

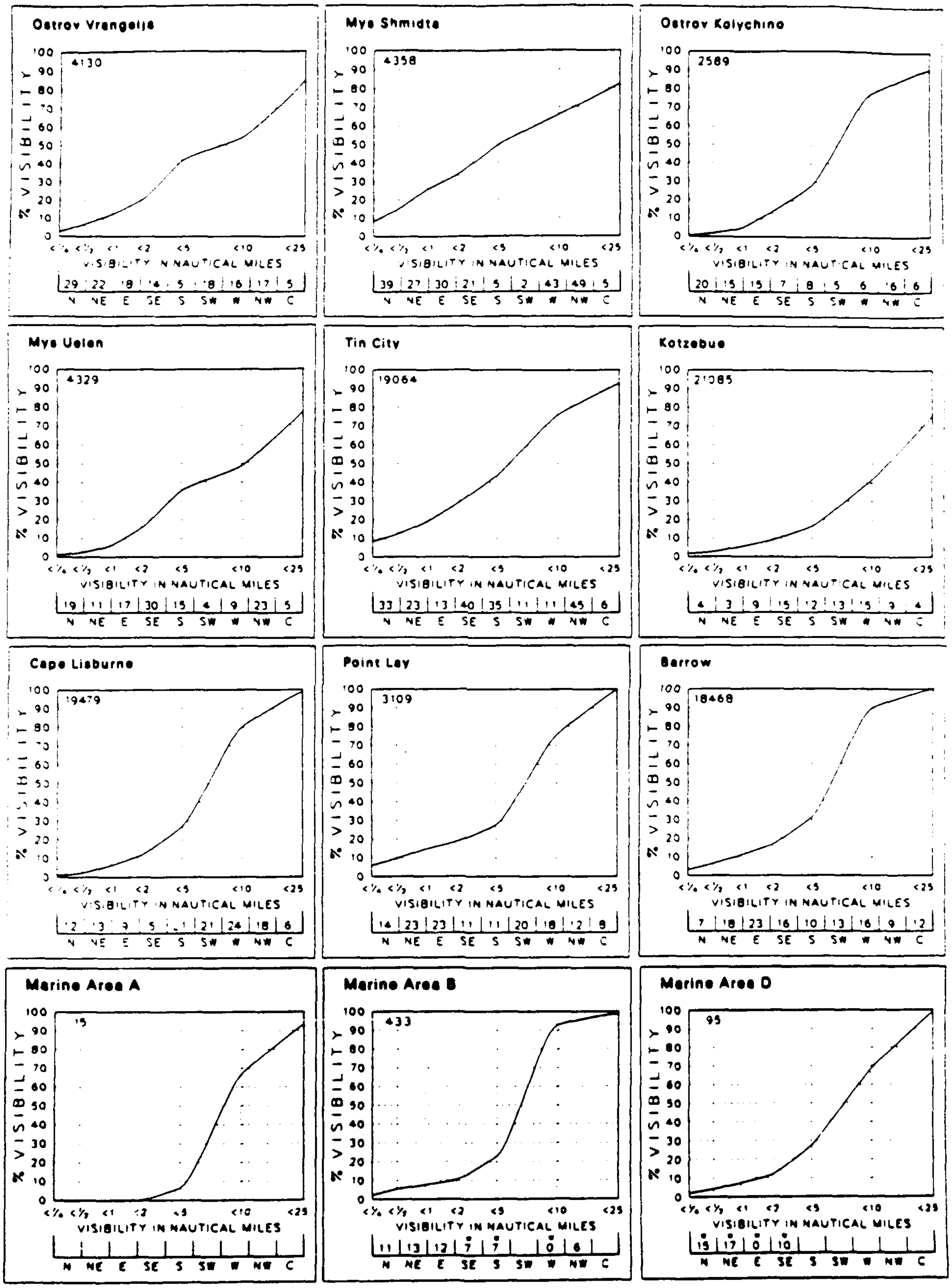


October

After Brower et al. 1988

Figure 29j

Visibility/Wind Direction

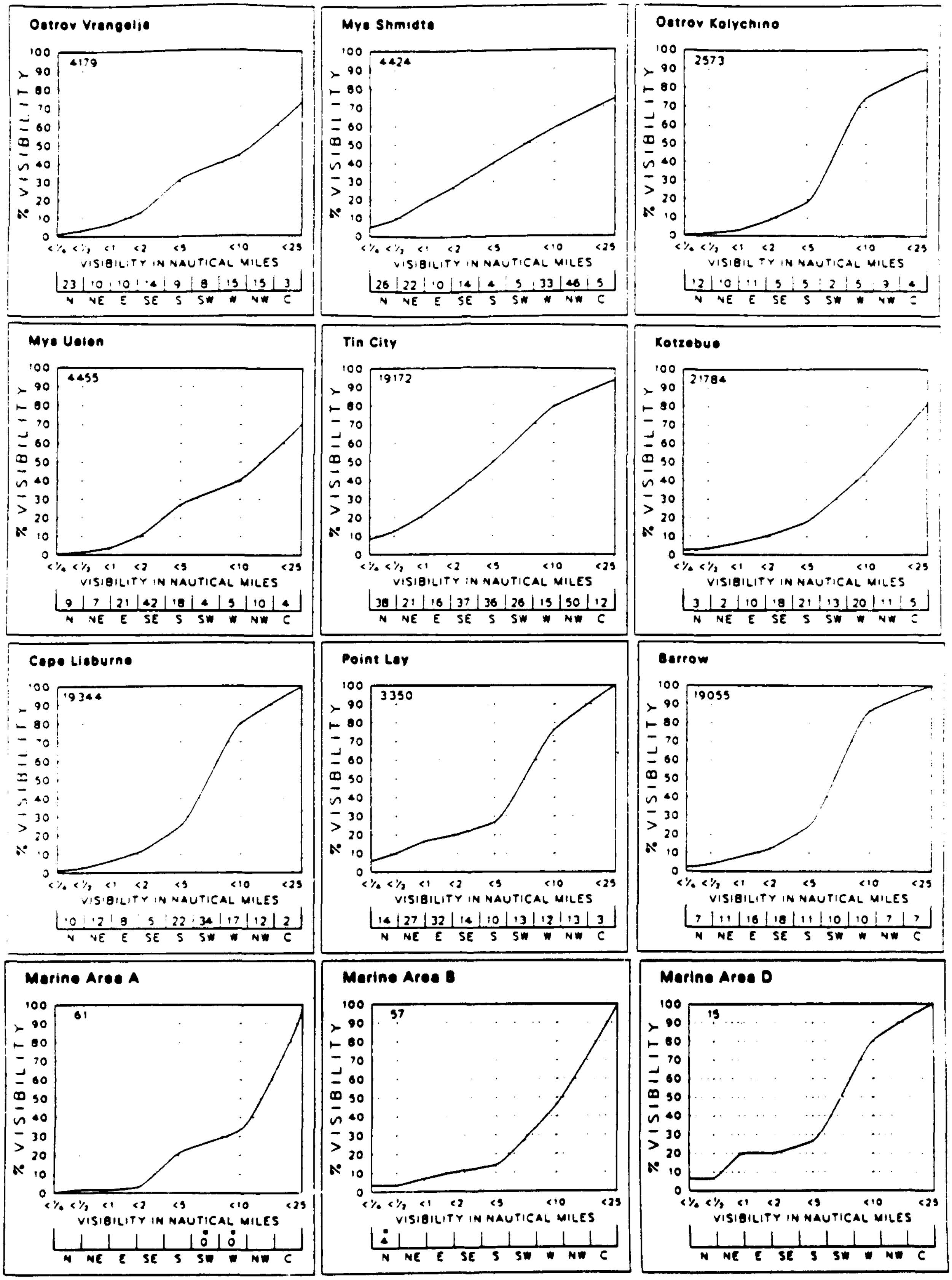


November

After Brower et al. 1988

Figure 29k

Visibility/Wind Direction

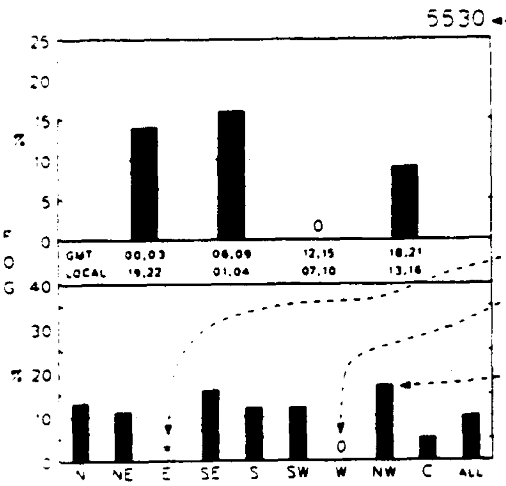


December

After Brower et al. 1988

Figure 291

Graphs: Fog/time and fog/wind direction



Number of observations.

Bar graphs represent percent frequency of fog (without precipitation) for various hour groupings and wind directions. Data are based on 100% for each hour-group and direction category.

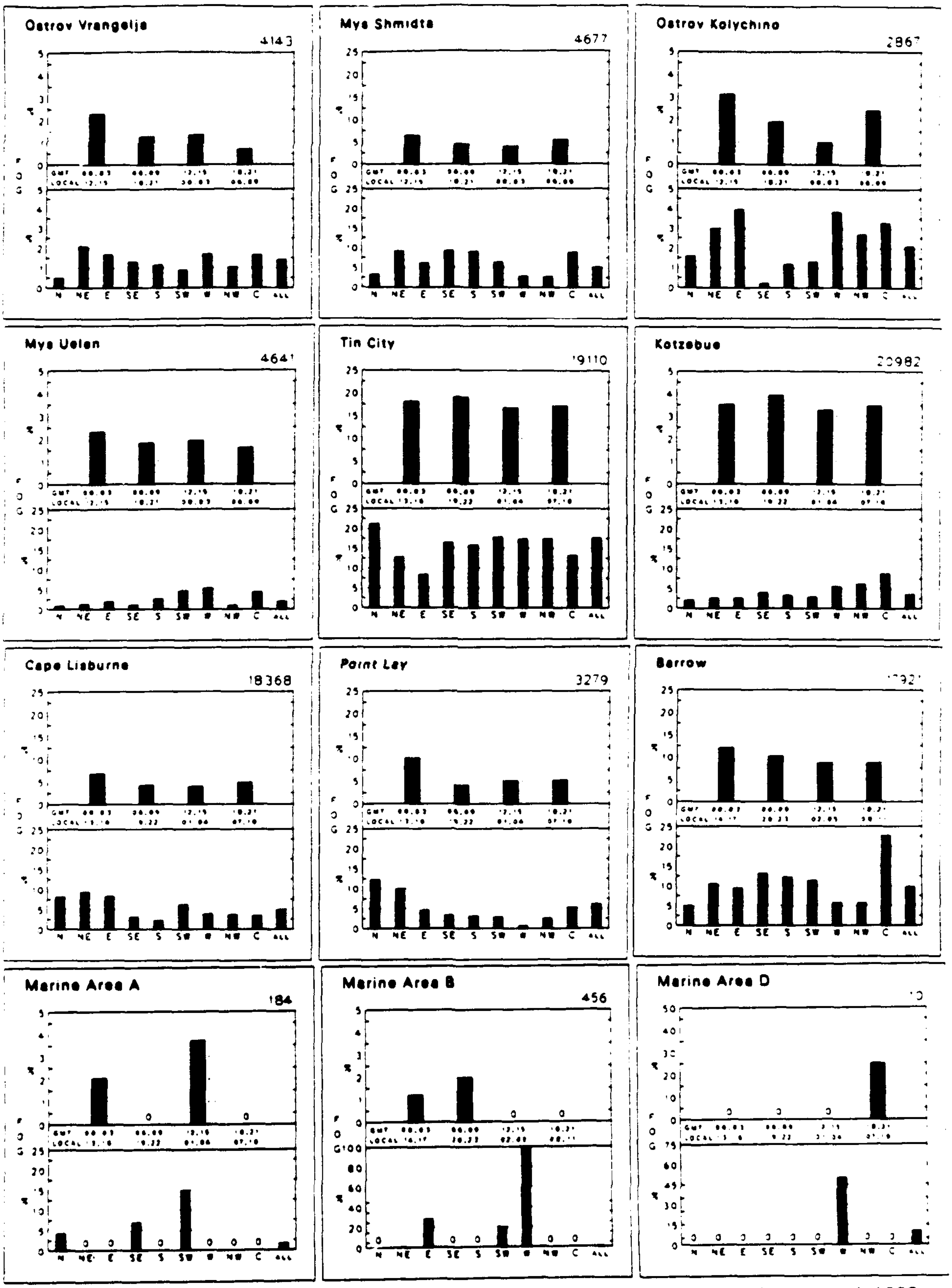
* indicates <.05% but >0.

0 indicates no fog occurred with the wind direction.

(Data show that 17% of all NW winds were accompanied by Fog (without precipitation).)

Figure 30

Fog Time/Fog Wind Direction

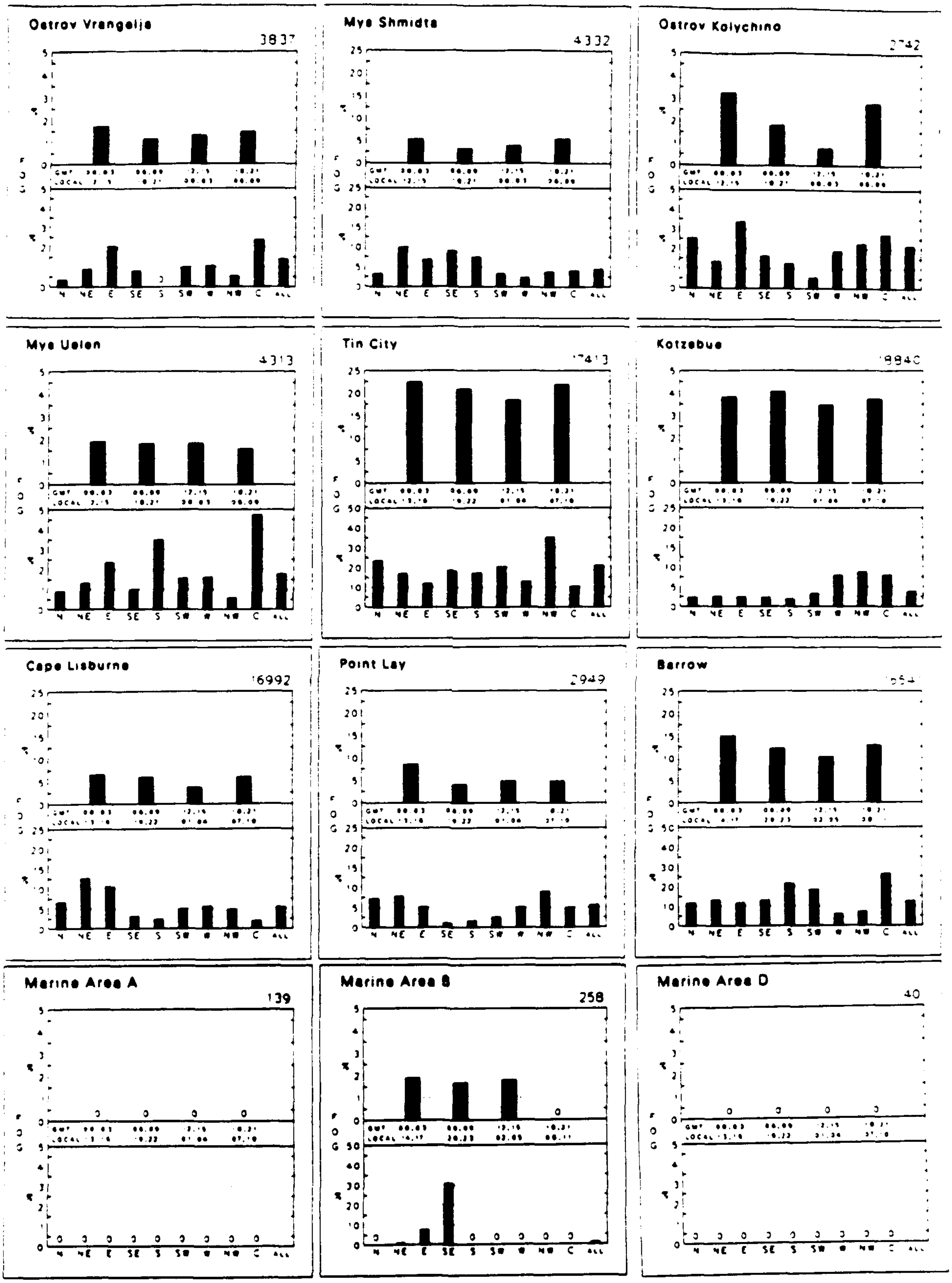


January

After Brower et al. 1988

Figure 30a

Fog Time/Fog Wind Direction

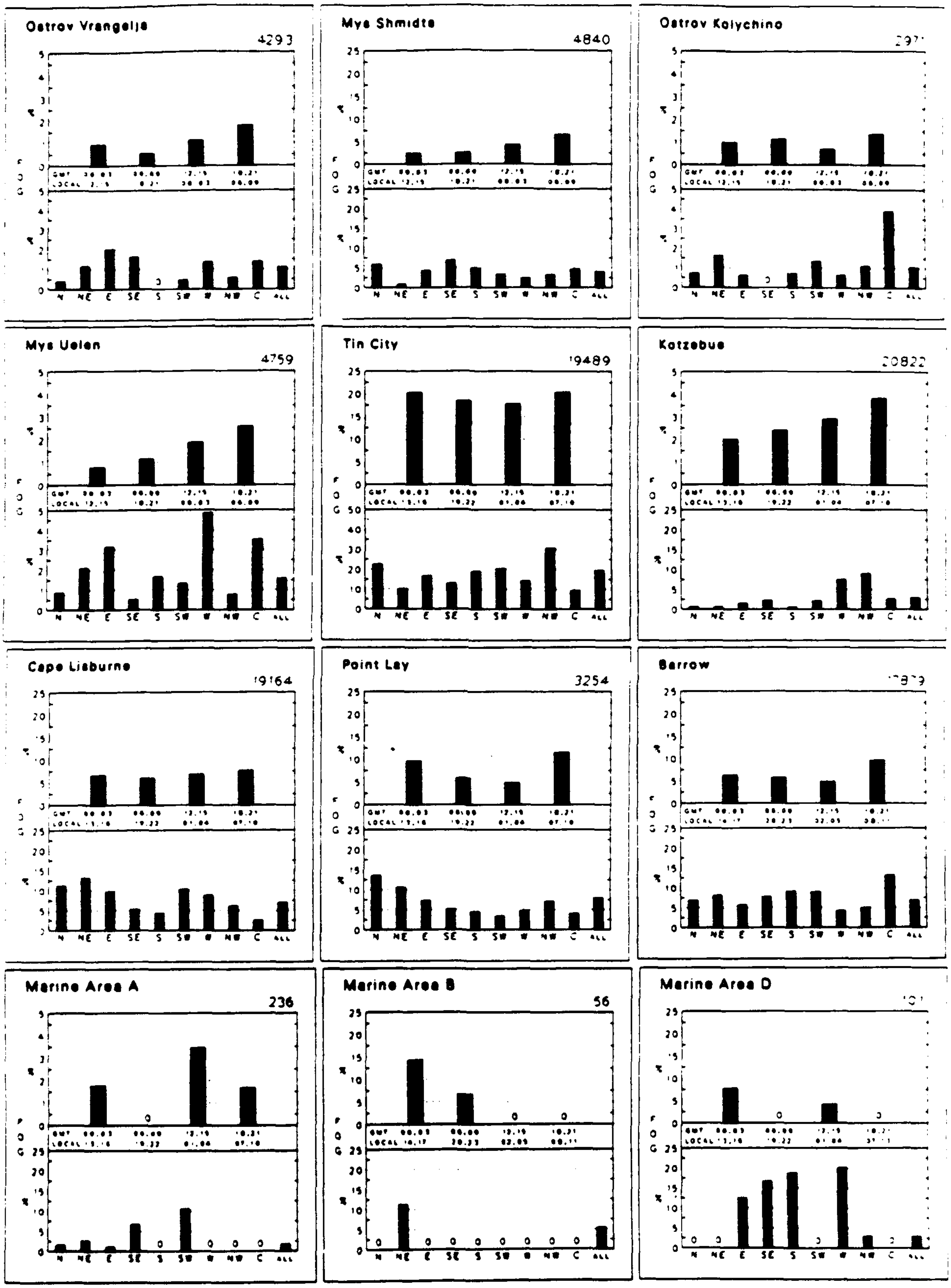


February

After Brower et al. 1988

Figure 30b

Fog Time/Fog Wind Direction

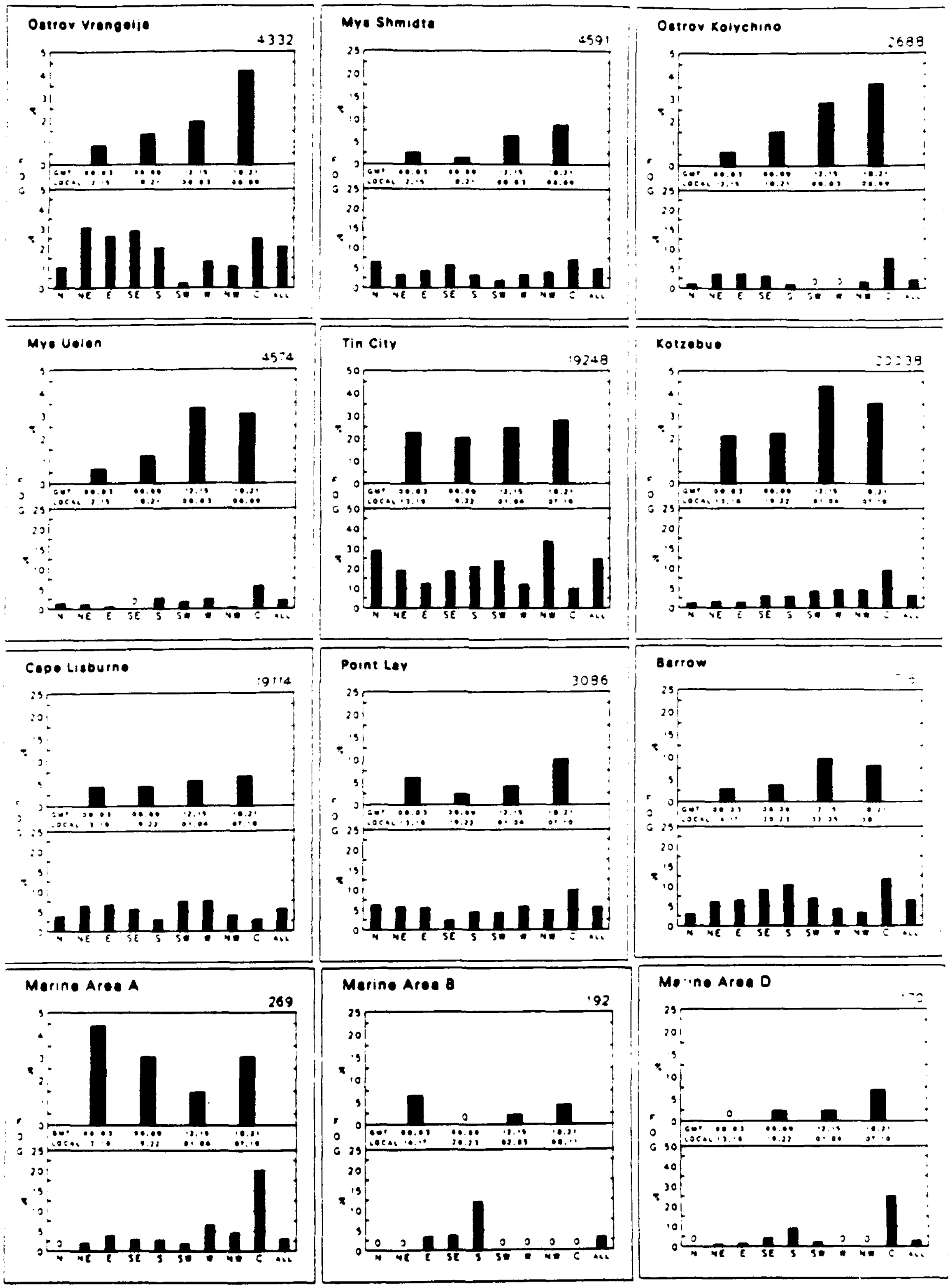


March

After Brower et al. 1988

Figure 30c

Fog Time/Fog Wind Direction

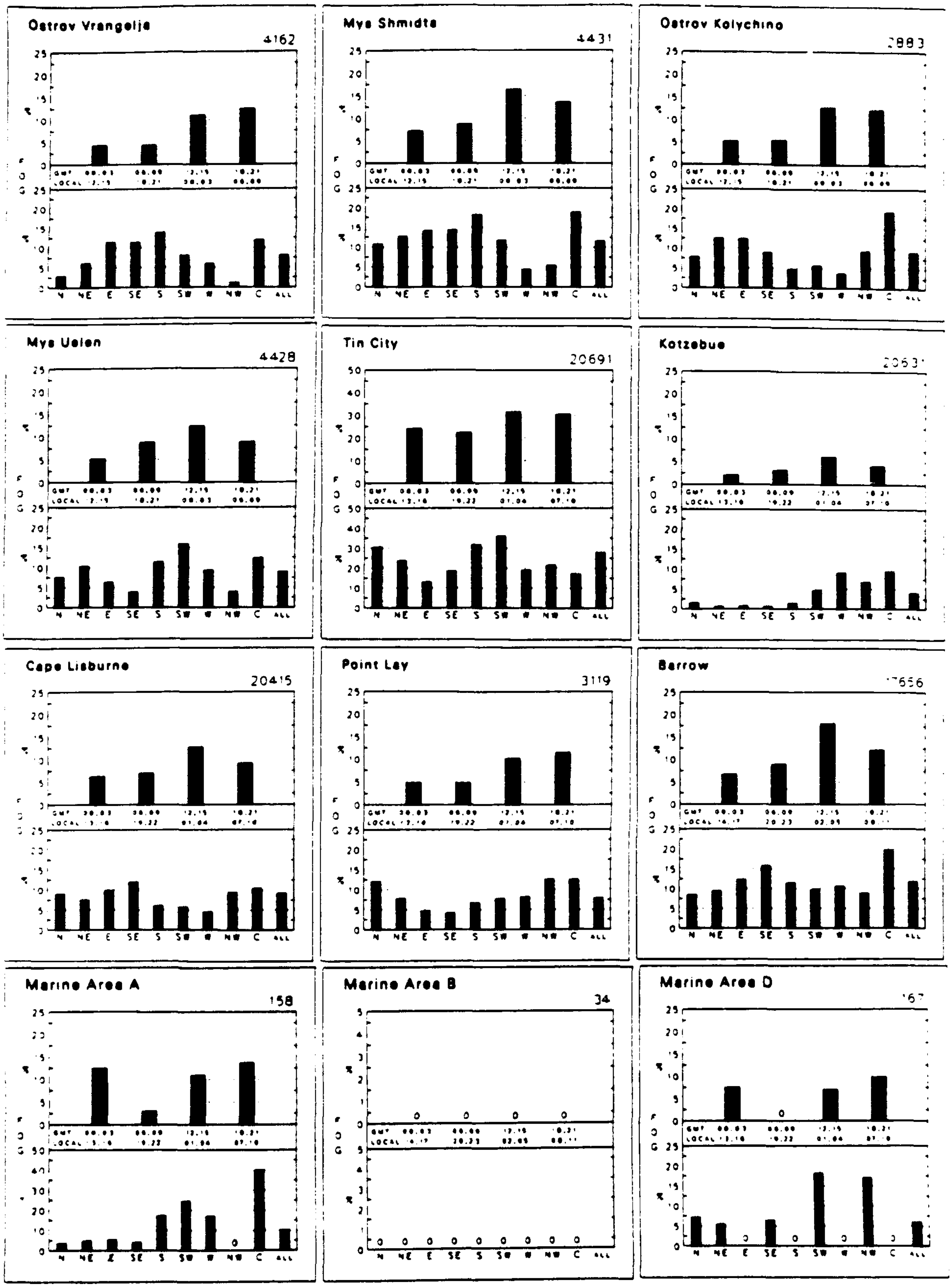


April

After Brower et al. 1988

Figure 30d

Fog Time/Fog Wind Direction

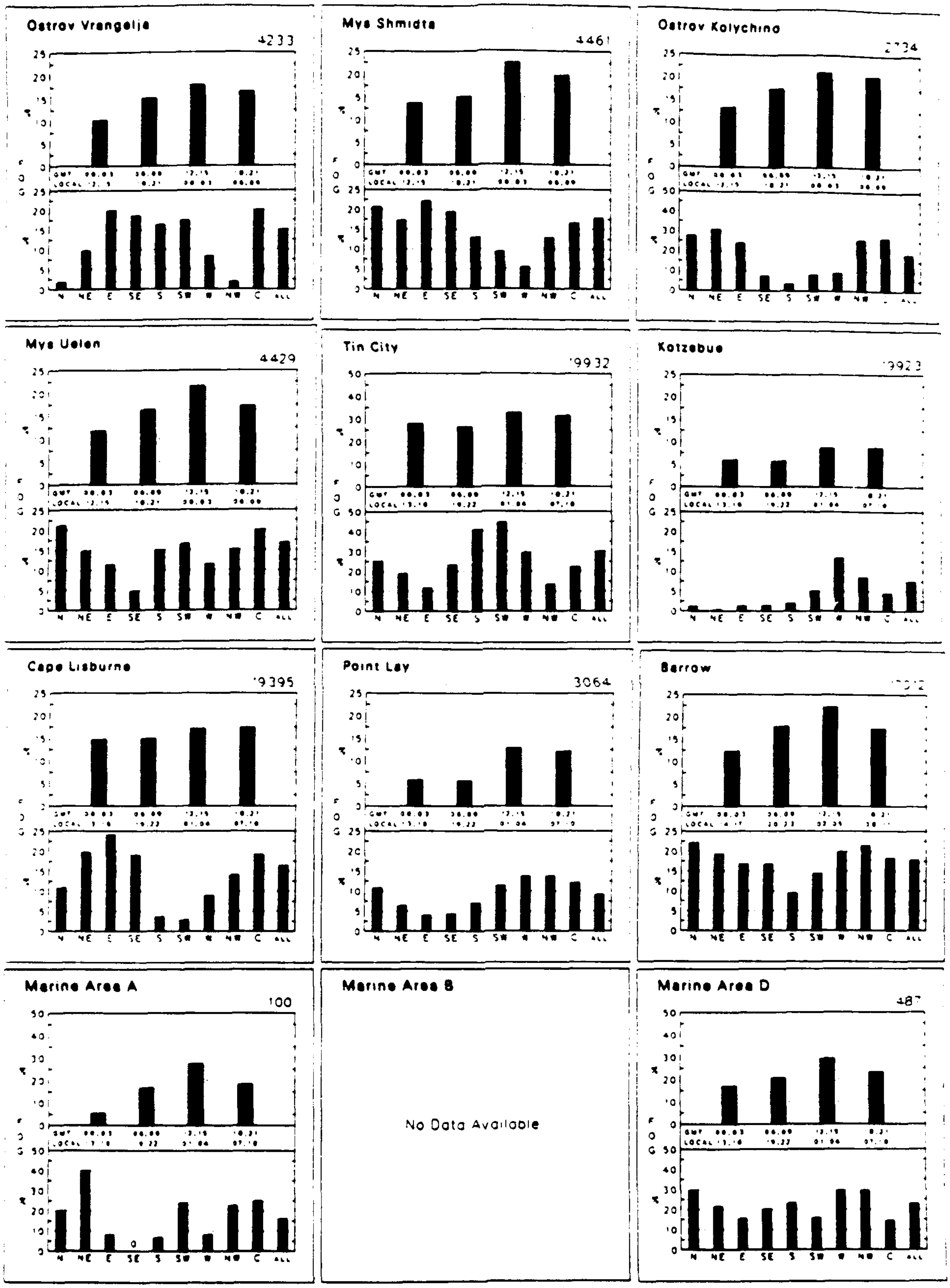


May

After Brower et al. 1988

Figure 30e

Fog Time/Fog Wind Direction

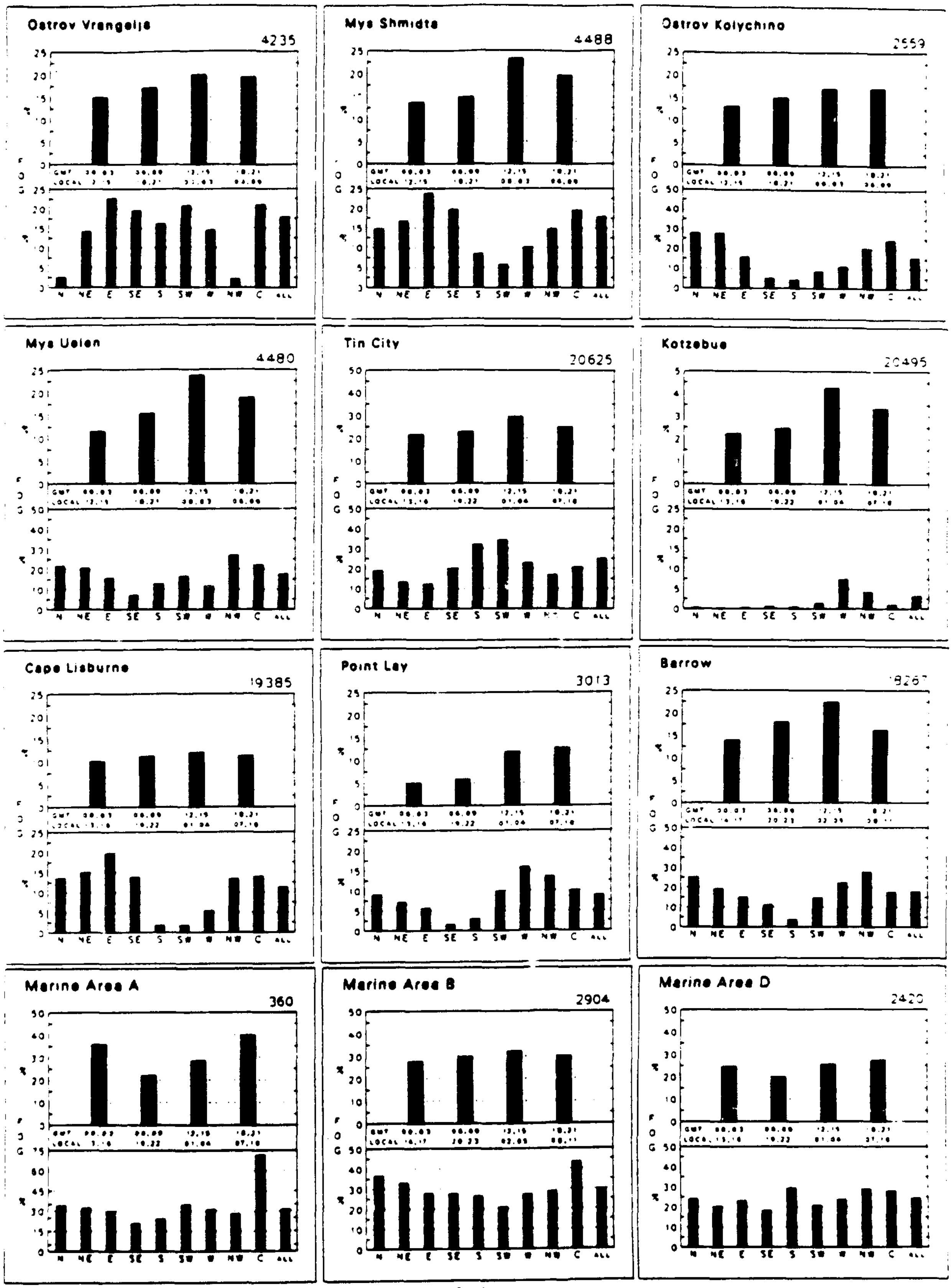


June

After Brower et al. 1988

Figure 30f

Fog Time/Fog Wind Direction

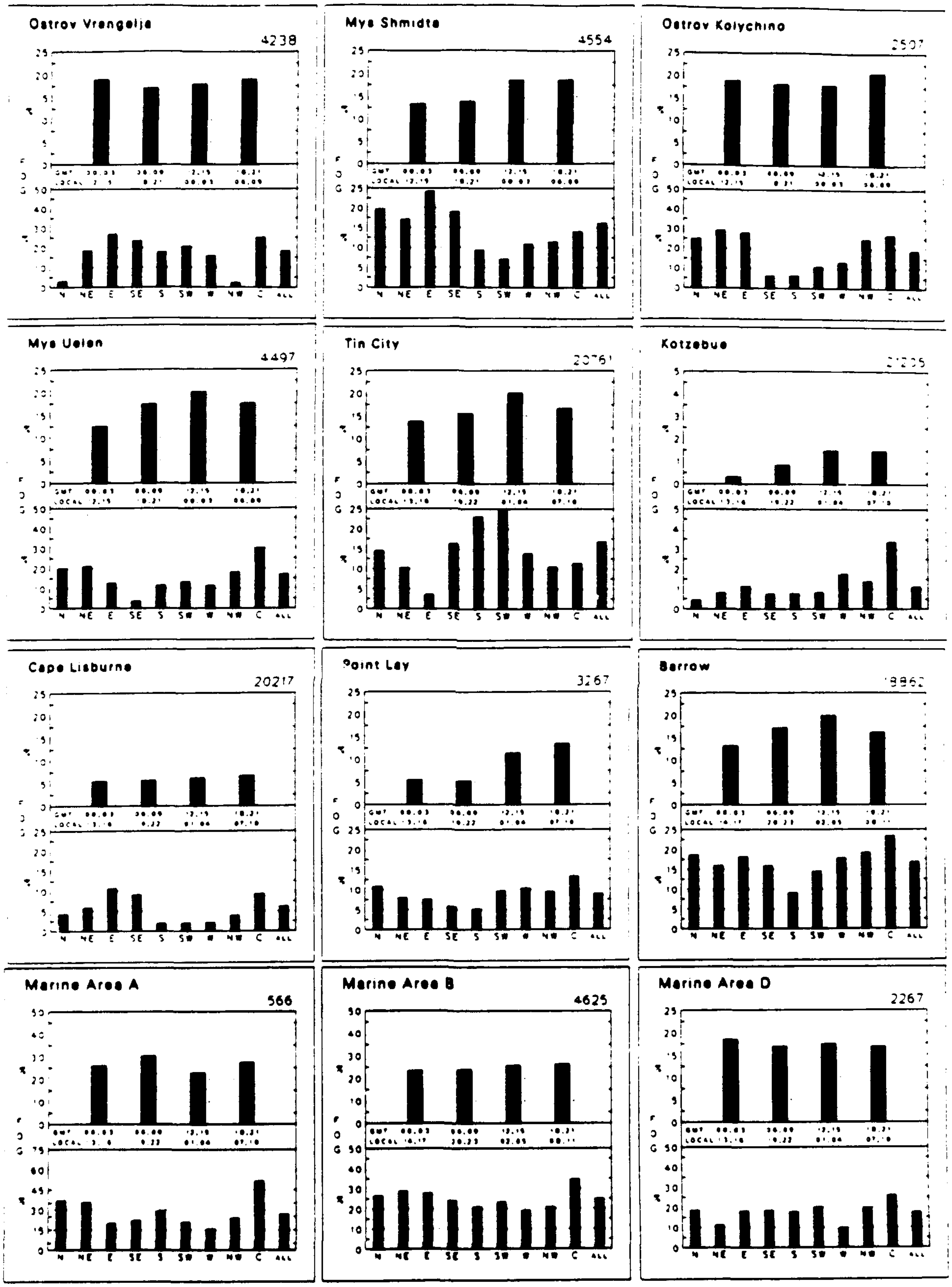


July

After Brower et al. 1988

Figure 30g

Fog Time/Fog Wind Direction

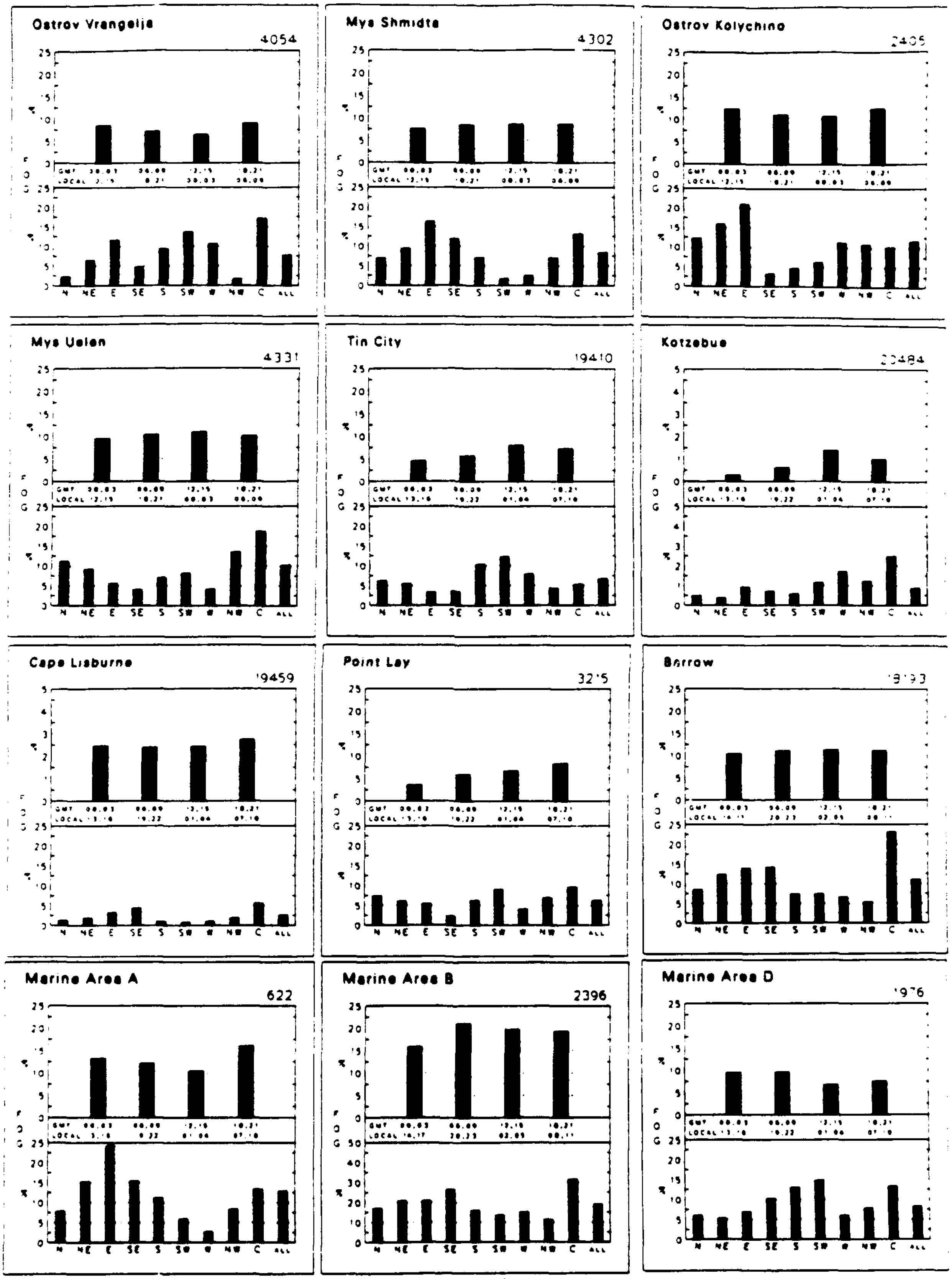


August

After Brower et al. 1988

Figure 30h

Fog Time/Fog Wind Direction

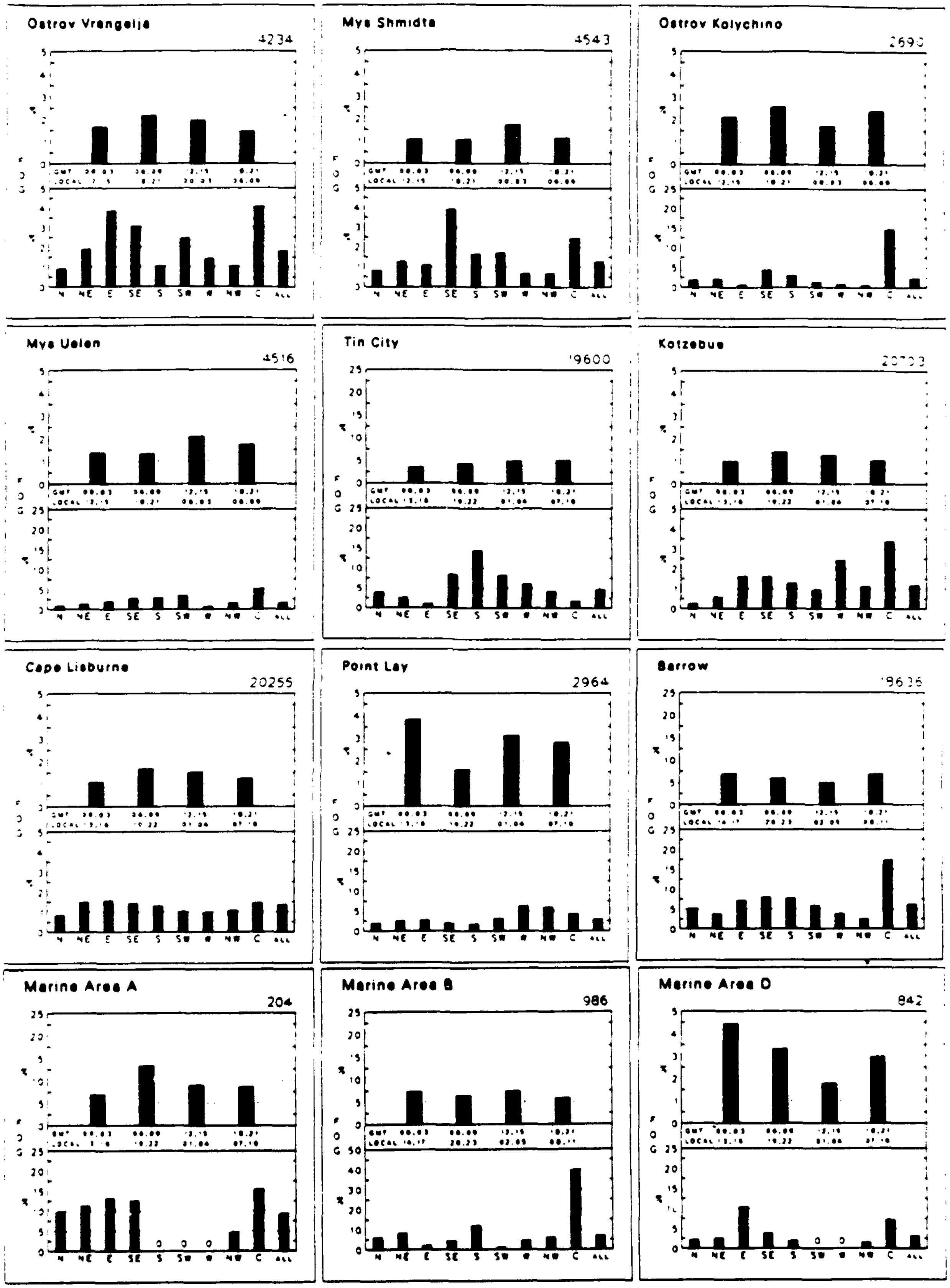


September

After Brower et al. 1988

Figure 30i

Fog Time/Fog Wind Direction

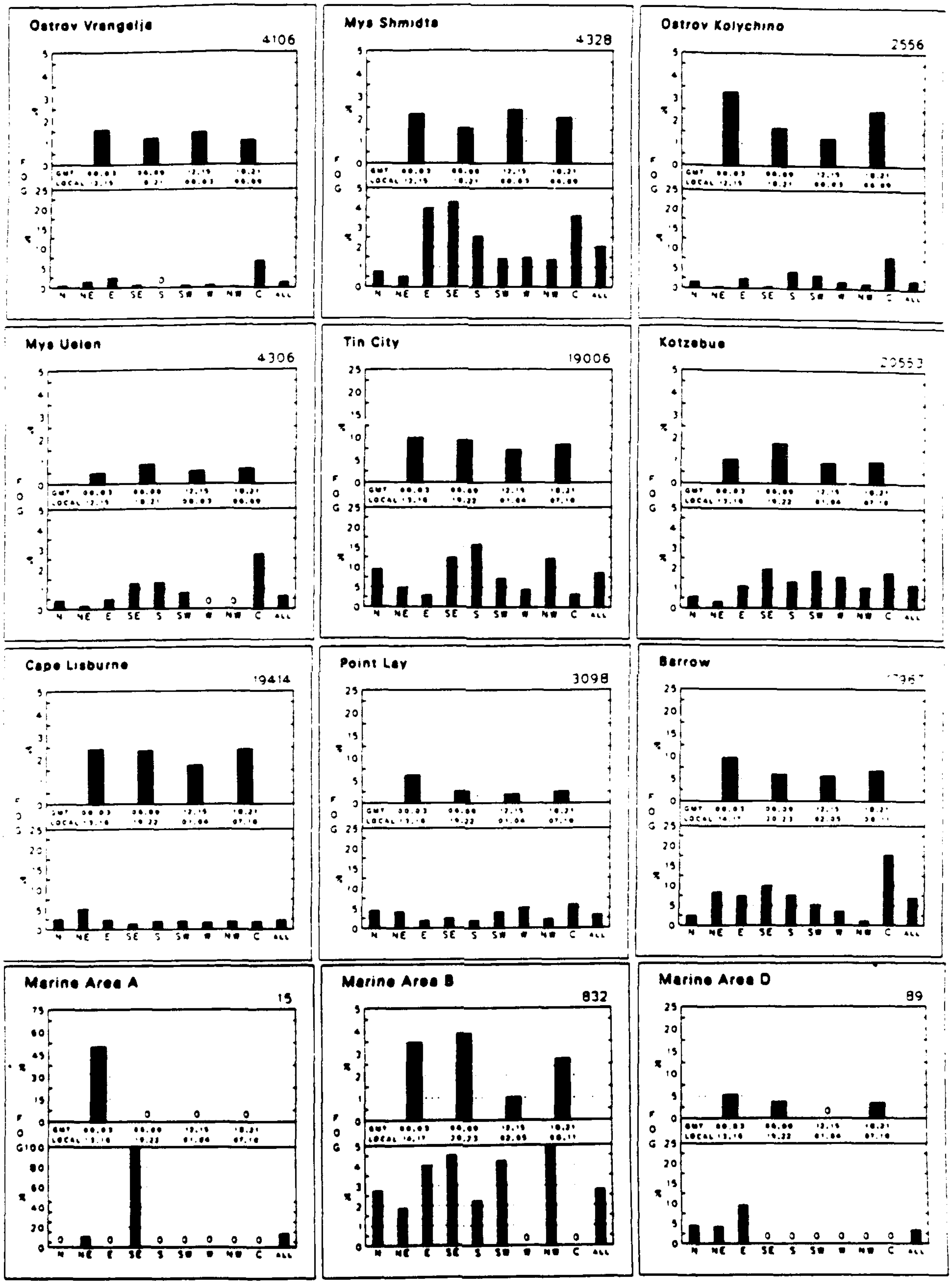


October

After Brower et al. 1988

Figure 30j

Fog Time/Fog Wind Direction

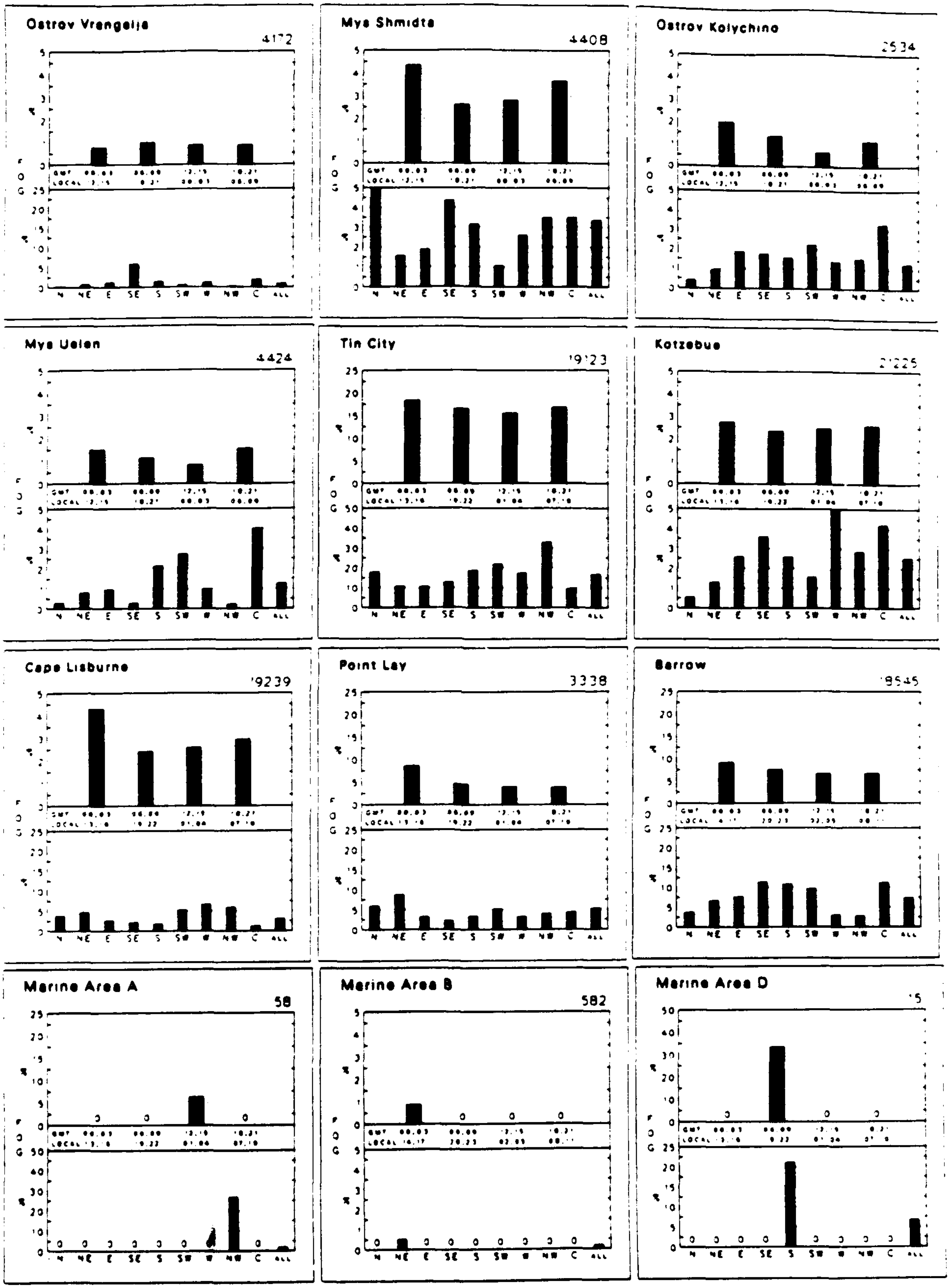


November

After Brower et al. 1988

Figure 30k

Fog Time/Fog Wind Direction



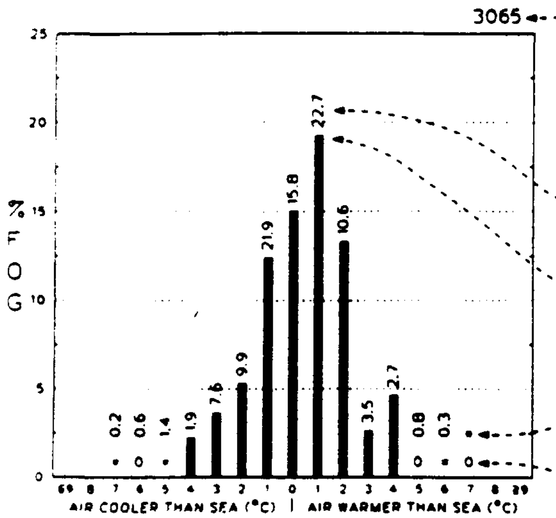
December

After Brower et al. 1988

Figure 30l

Graphs: Fog/air-sea temperature difference

PERCENT FREQUENCY OF THE OCCURRENCE OF FOG (Without Precipitation) VERSUS AIR-SEA TEMPERATURE DIFFERENCE (°C)



Number of observations.

Bars show the percentage of observations with Fog (without Precipitation) for each Air-Sea temperature difference category. Plotted numbers indicate the percentage of observations in each Air-Sea temperature difference category.

(22.7% of all observations had air-sea temperature difference of +1 °C.)

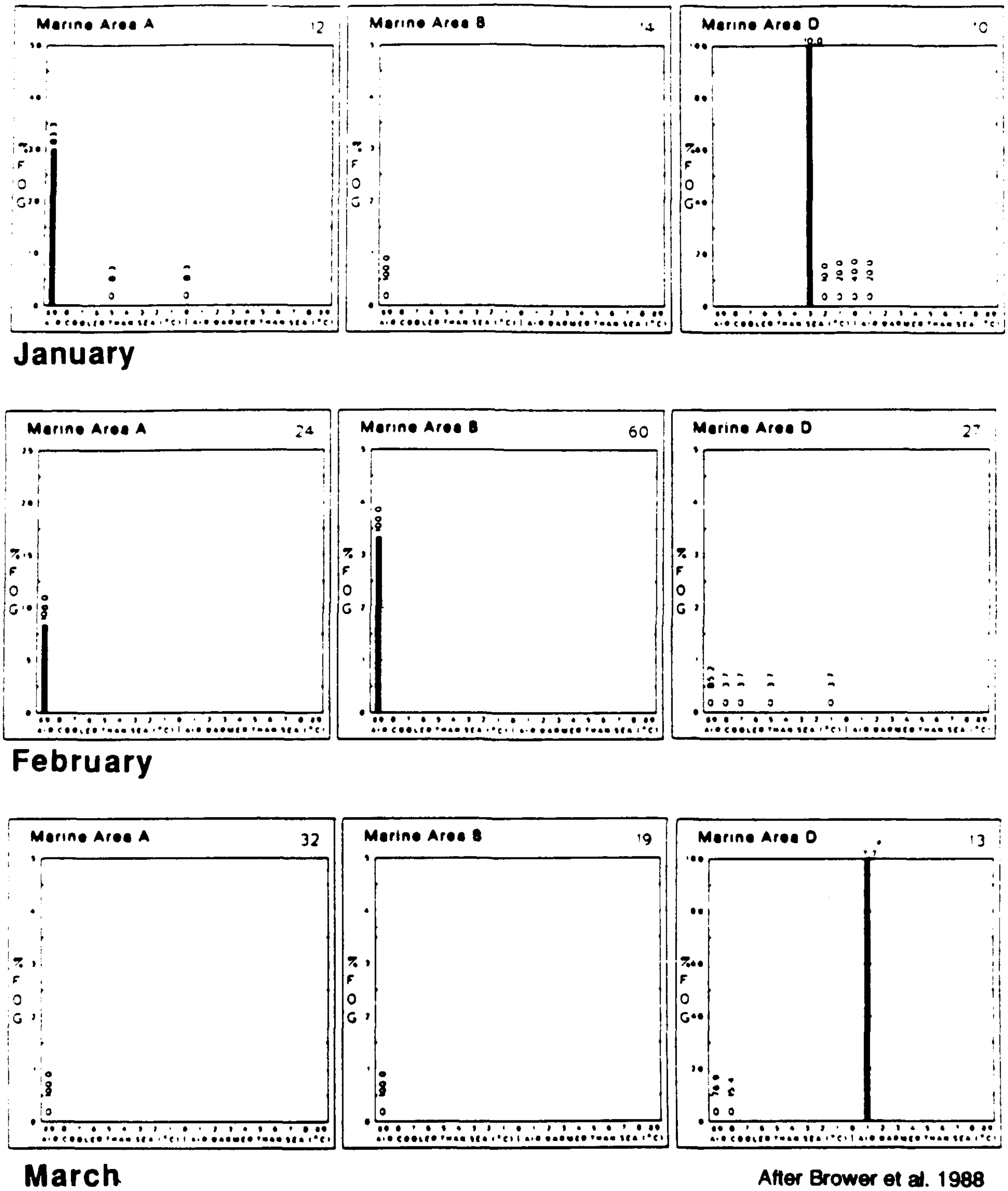
(19% of all observations with air-sea temperature difference of +1 °C were accompanied by fog (without precipitation).)

* indicates <.05% but >0.

0 indicates no fog with the air-sea temperature difference category.

Figure 31

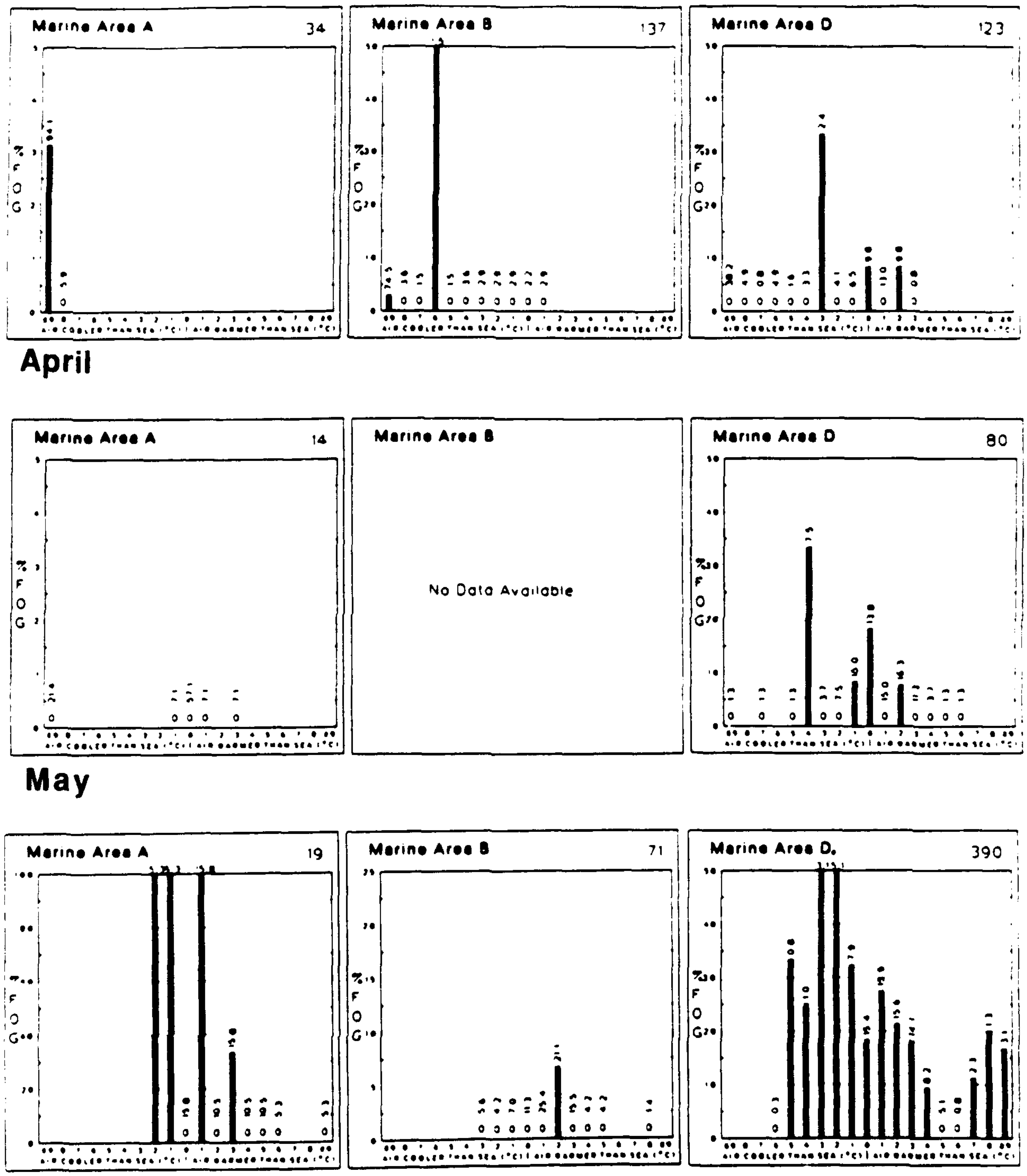
Fog/Air Sea Temperature Differences



After Brower et al. 1988

Figure 31a

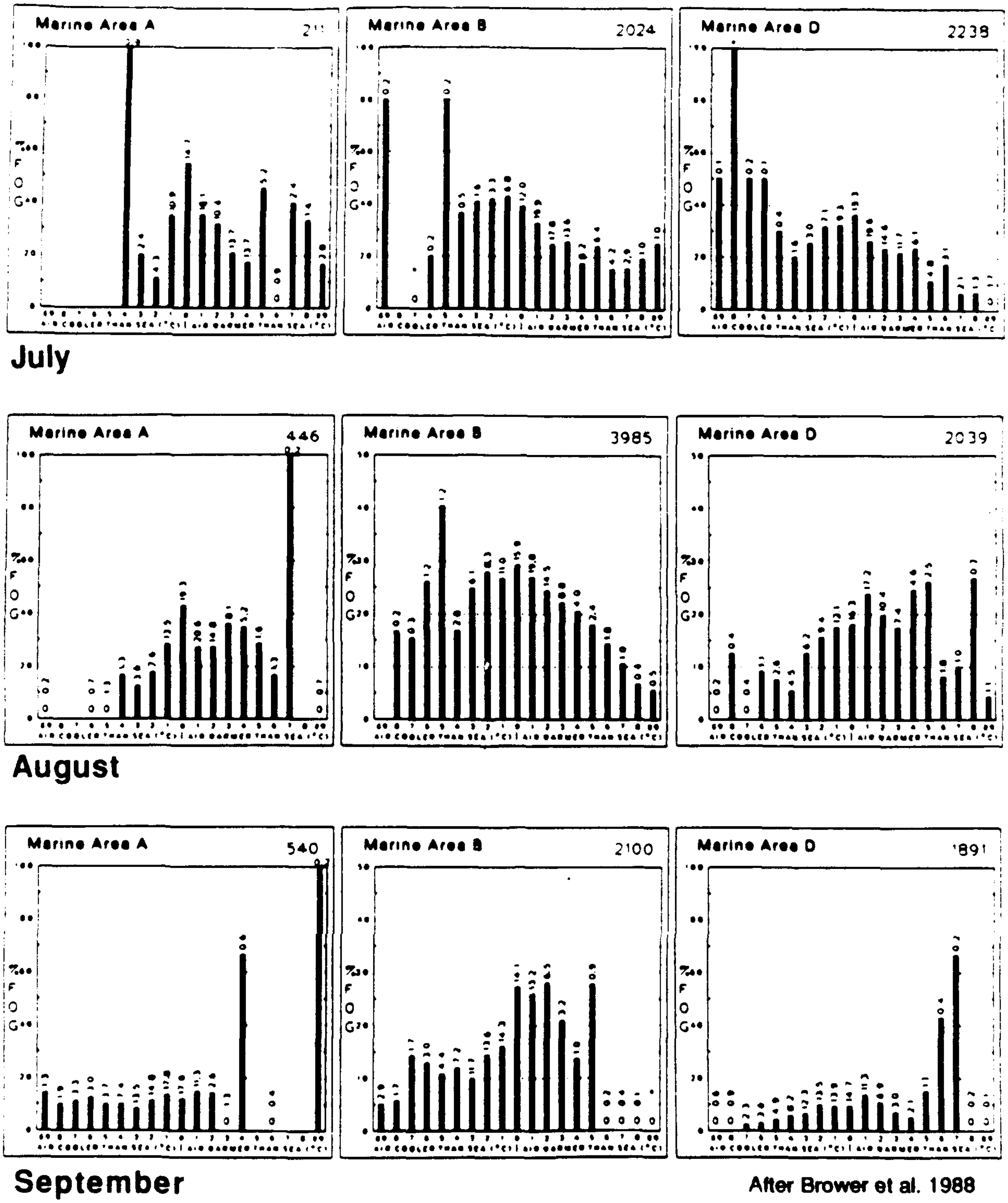
Fog/Air Sea Temperature Differences



After Brower et al. 1988

Figure 31b

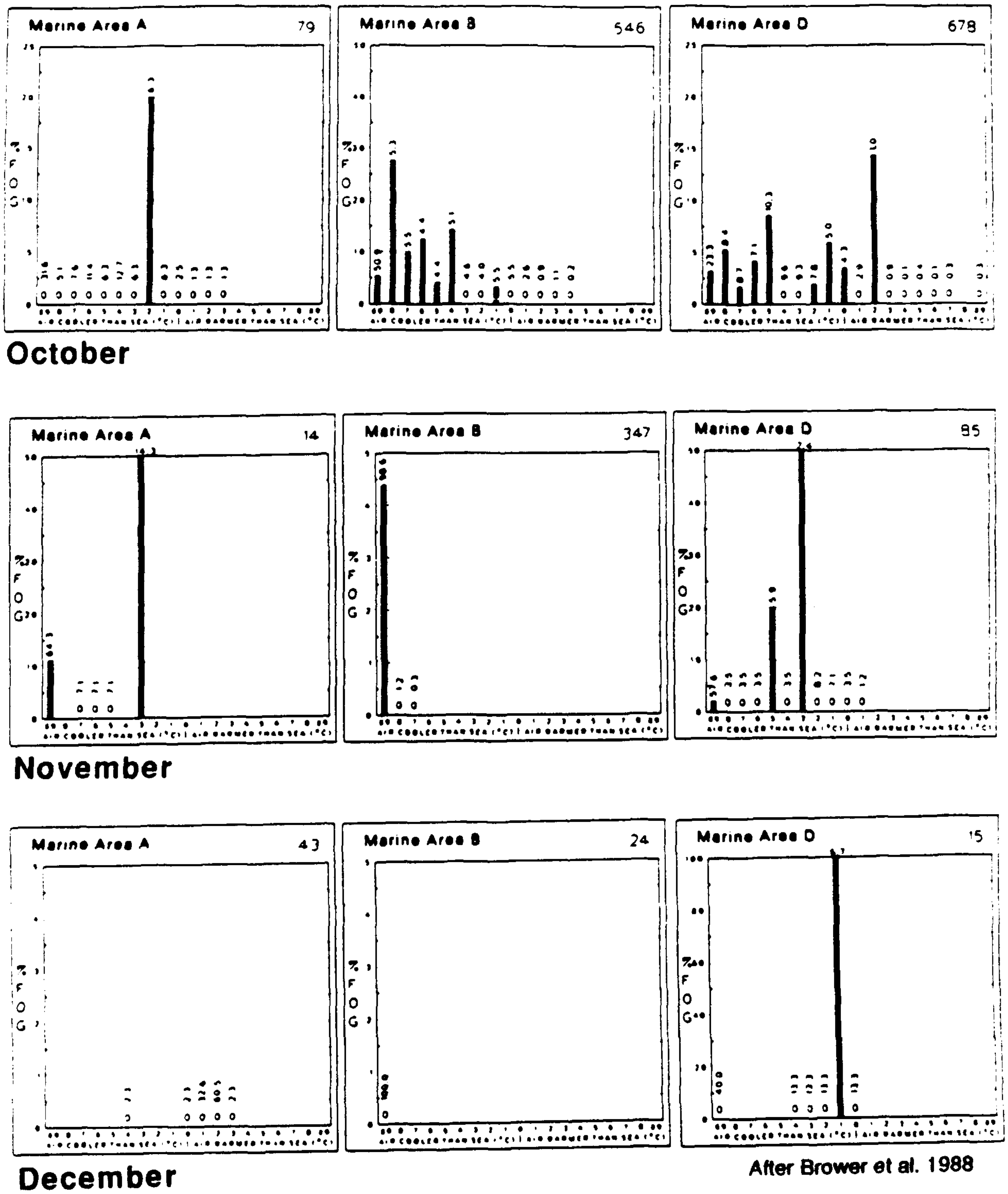
Fog/Air Sea Temperature Differences



After Brower et al. 1988

Figure 31c

Fog/Air Sea Temperature Differences



After Brower et al. 1988

Figure 31d

CLOUDINESS

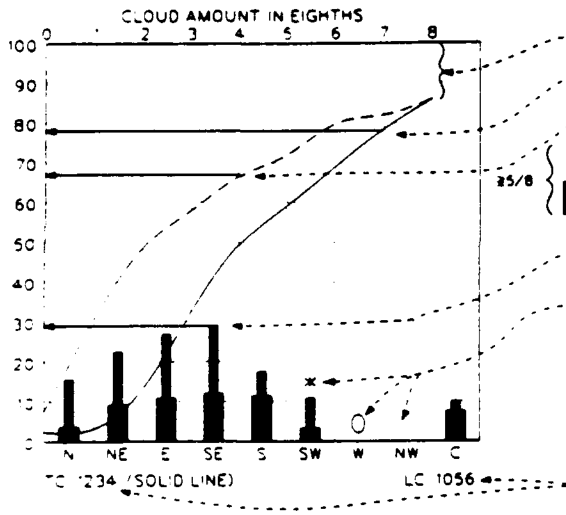
Cloudiness can be a factor in oil spill control or reconnaissance operations using aircraft. Low-stratus clouds are more common in the warmer months as warm air passes over ice surfaces, takes up moisture and form cloud. An estimate of the seasonal and geographical relationship of clouds to octant wind direction is the most practical way to present useful information to the OSC.

Figures 32a-32l show the amount of cloud cover coincidental with various wind directions.

Graphs: Cloud cover/wind direction

Total Cloud Amount
Low Cloud Amount

Cumulative percent frequency of indicated cloud amount equal to or less than the amount intersected by the curve.



Obscurations.

(78% of all total cloud amounts were ≤7/8.)

(67% of all low cloud amounts were ≤4/8.)

5/8 & 6/8, ≥7/8: Low cloud amount: Percent frequency of observations from each direction and calm that were accompanied by low cloud amounts ≥5/8 and ≥7/8 (including obscurations). Low clouds are clouds with bases <8000 feet.

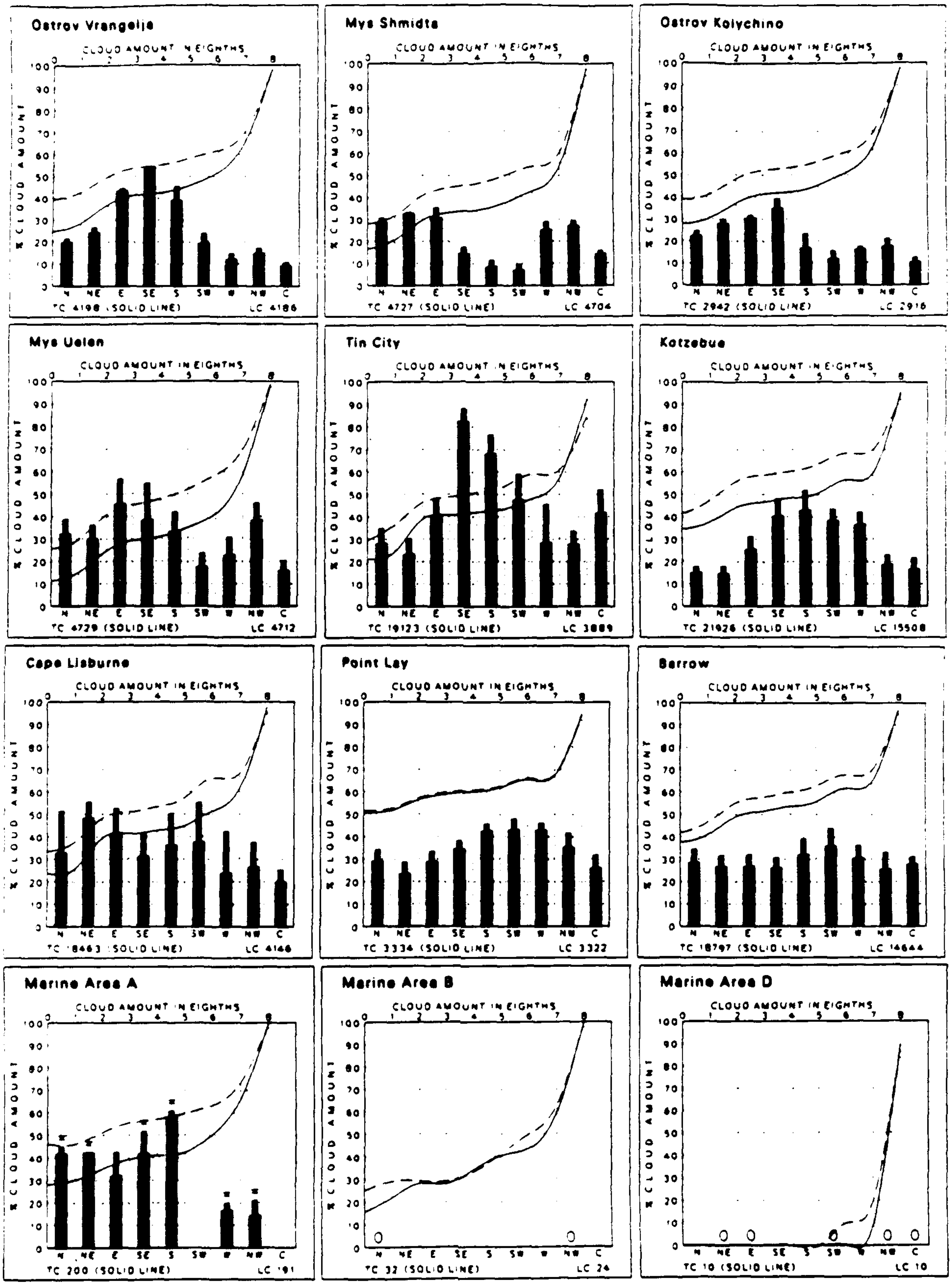
(29% of all SE winds were accompanied by low cloud amounts ≥5/8 and 12% by low cloud amounts ≥7/8.)

An asterisk indicates that the percentage is based on 10-30 observations of wind direction, total and low cloud amount. O replaces bar graph when no low cloud amounts ≥5/8 were observed with a wind direction or calm. O or bar is omitted when number of observations of total and low cloud amount from a wind direction or calm is less than 10.

Number of total cloud (TC) and low cloud (LC) observations.

Figure 32

Cloud Cover/Wind Direction

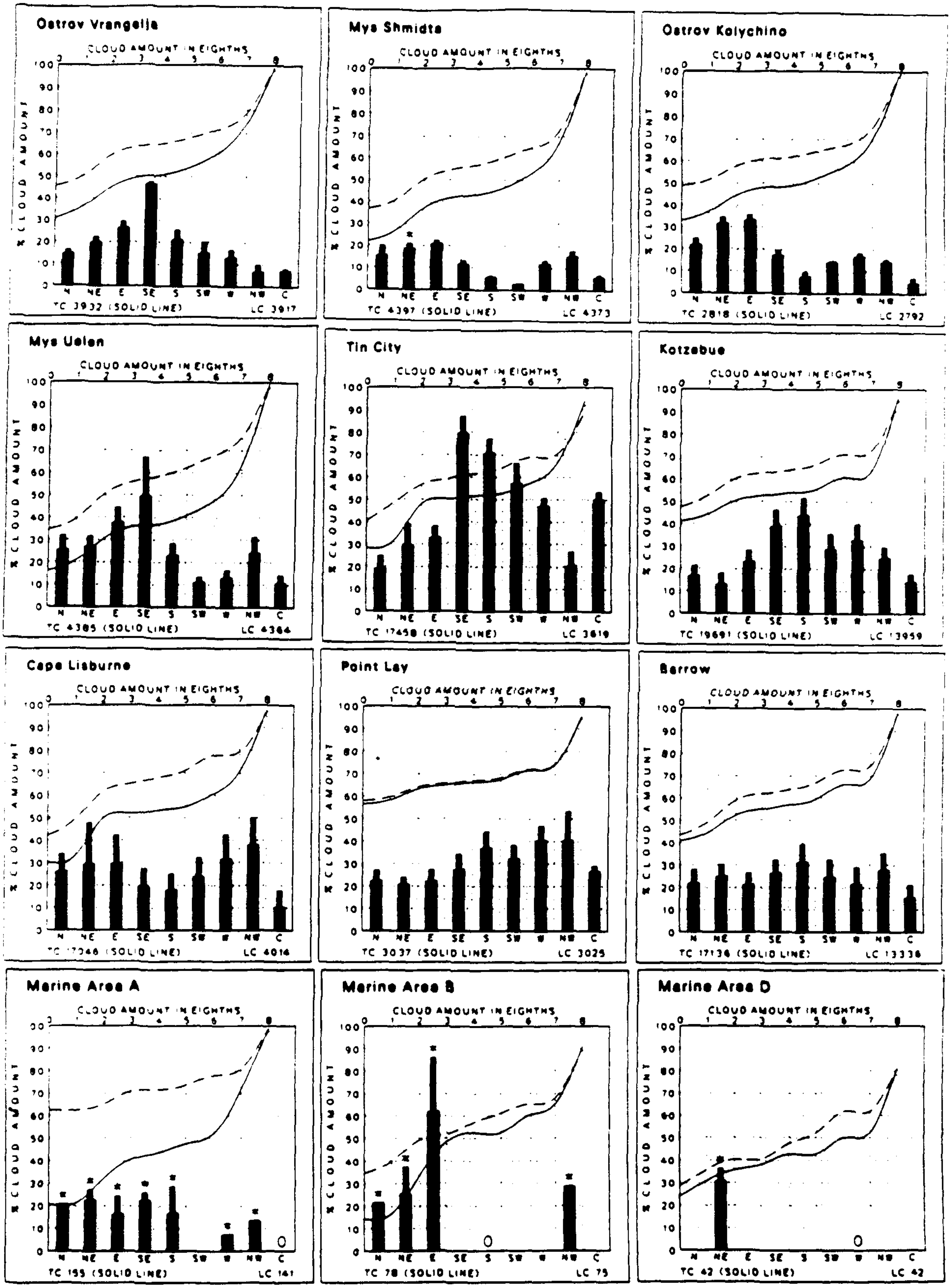


January

After Brower et al. 1988

Figure 32a

Cloud Cover/Wind Direction

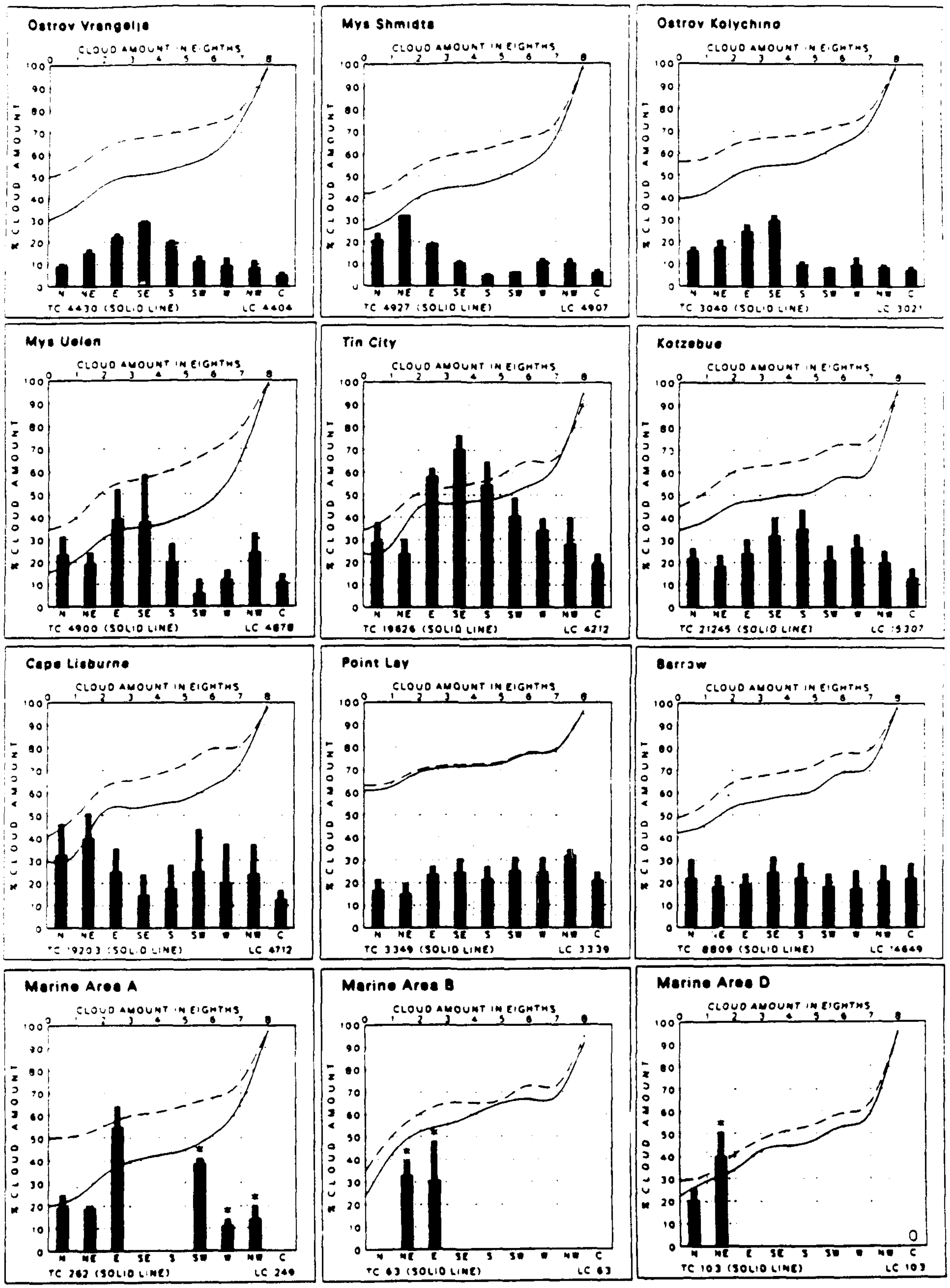


February

After Brower et al. 1988

Figure 32b

Cloud Cover/Wind Direction

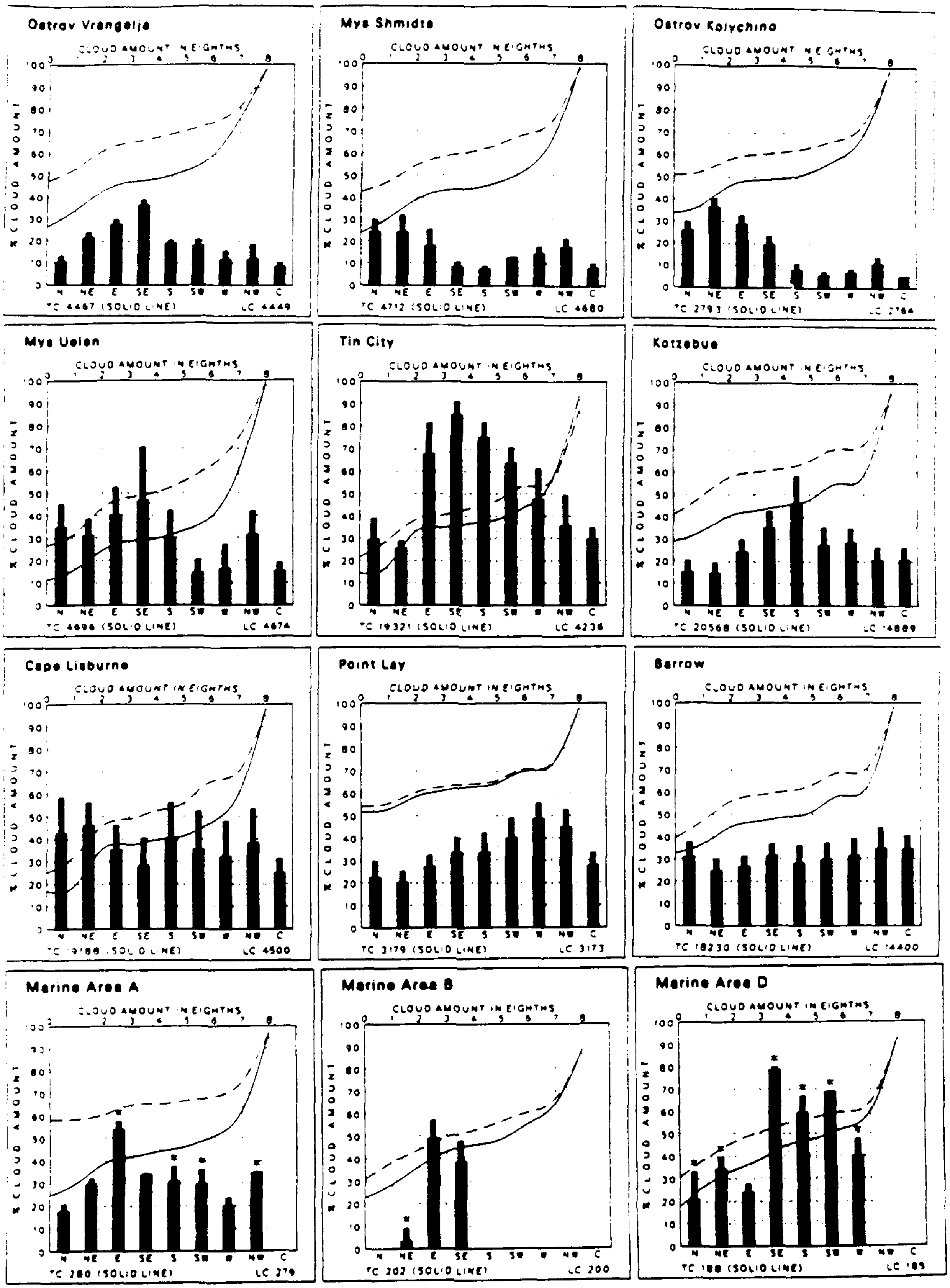


March

After Brower et al. 1988

Figure 32c

Cloud Cover/Wind Direction

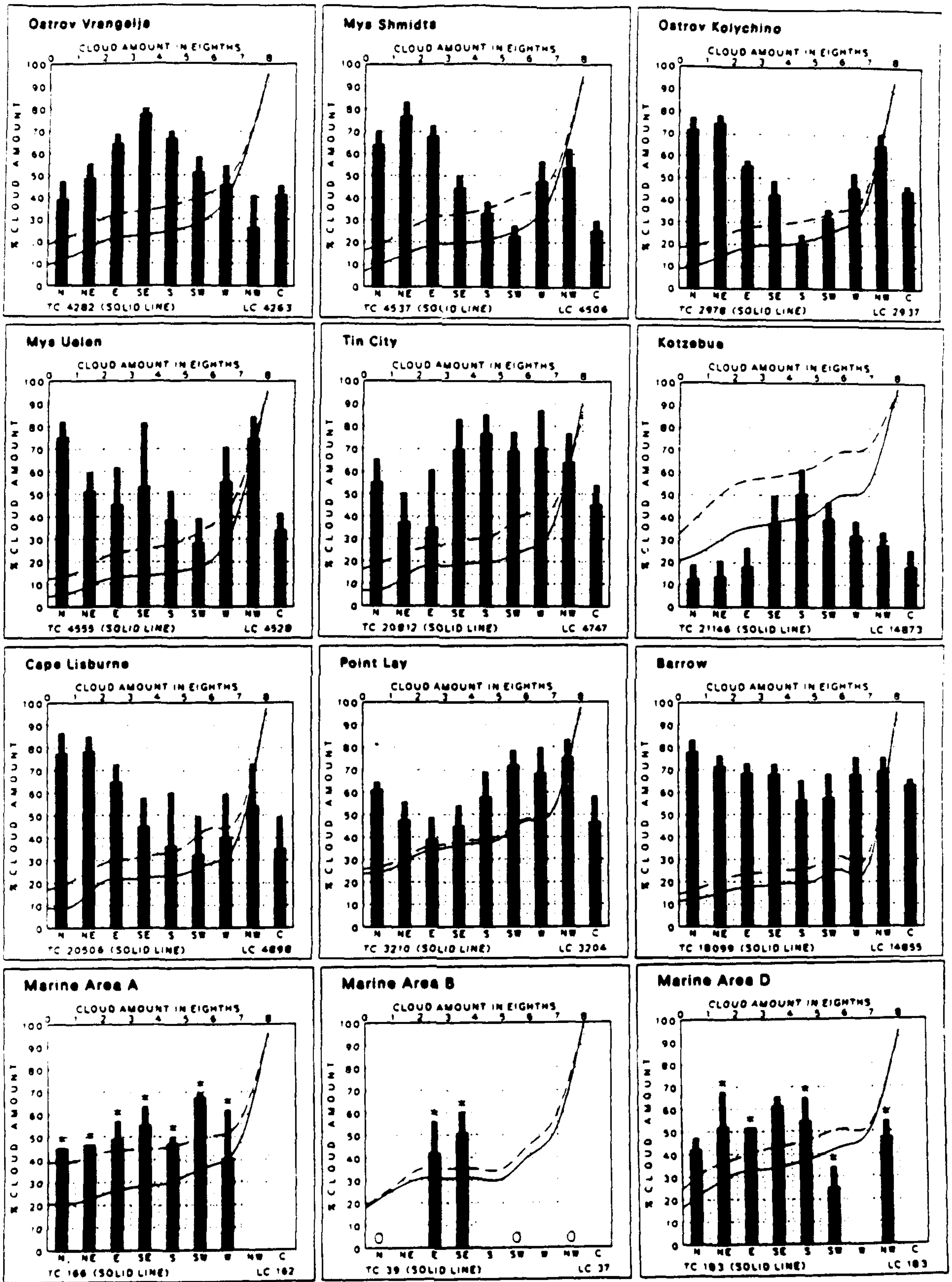


April

After Brower et al. 1988

Figure 32d

Cloud Cover/Wind Direction

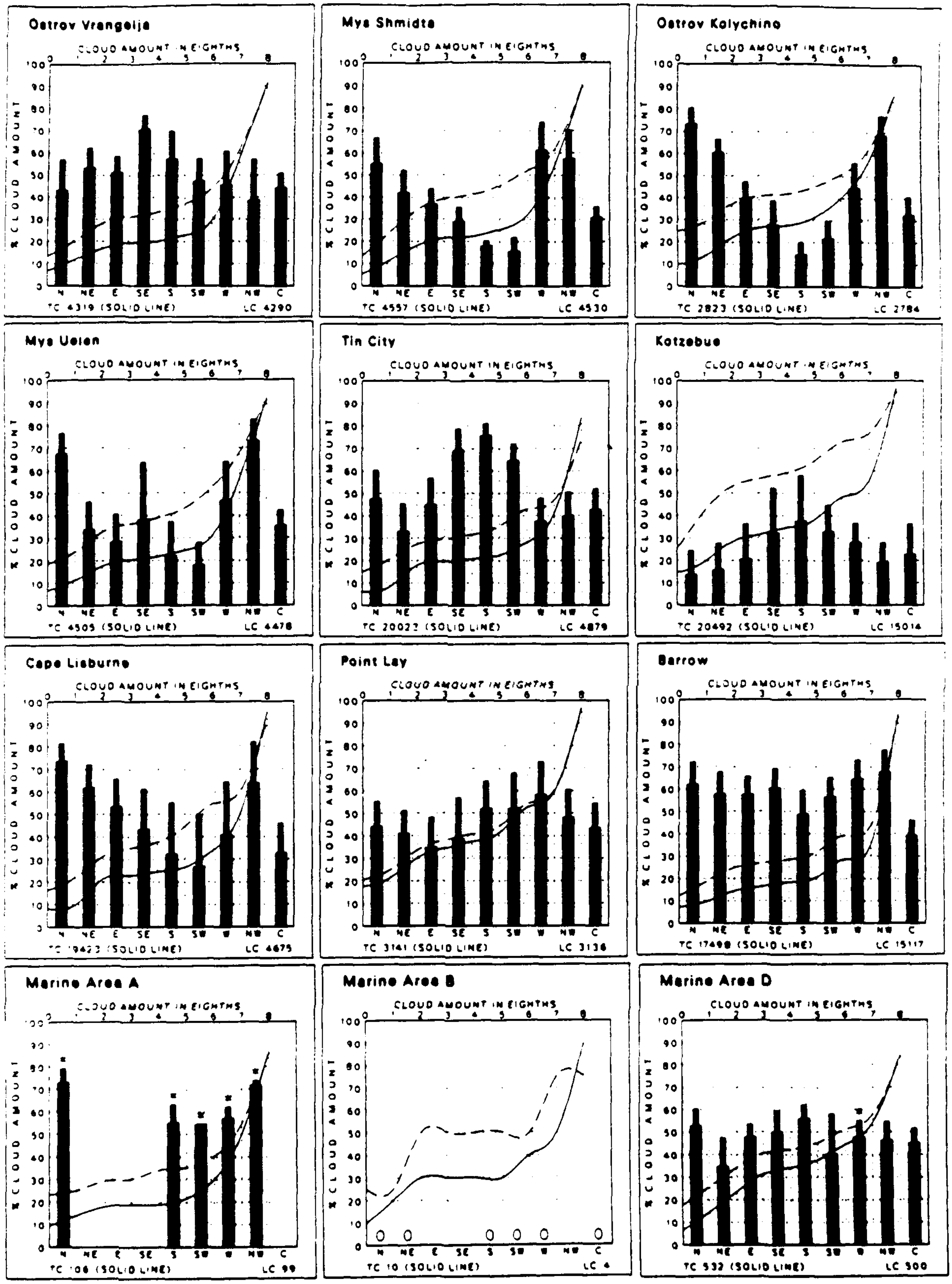


May

After Brower et al. 1988

Figure 32e

Cloud Cover/Wind Direction

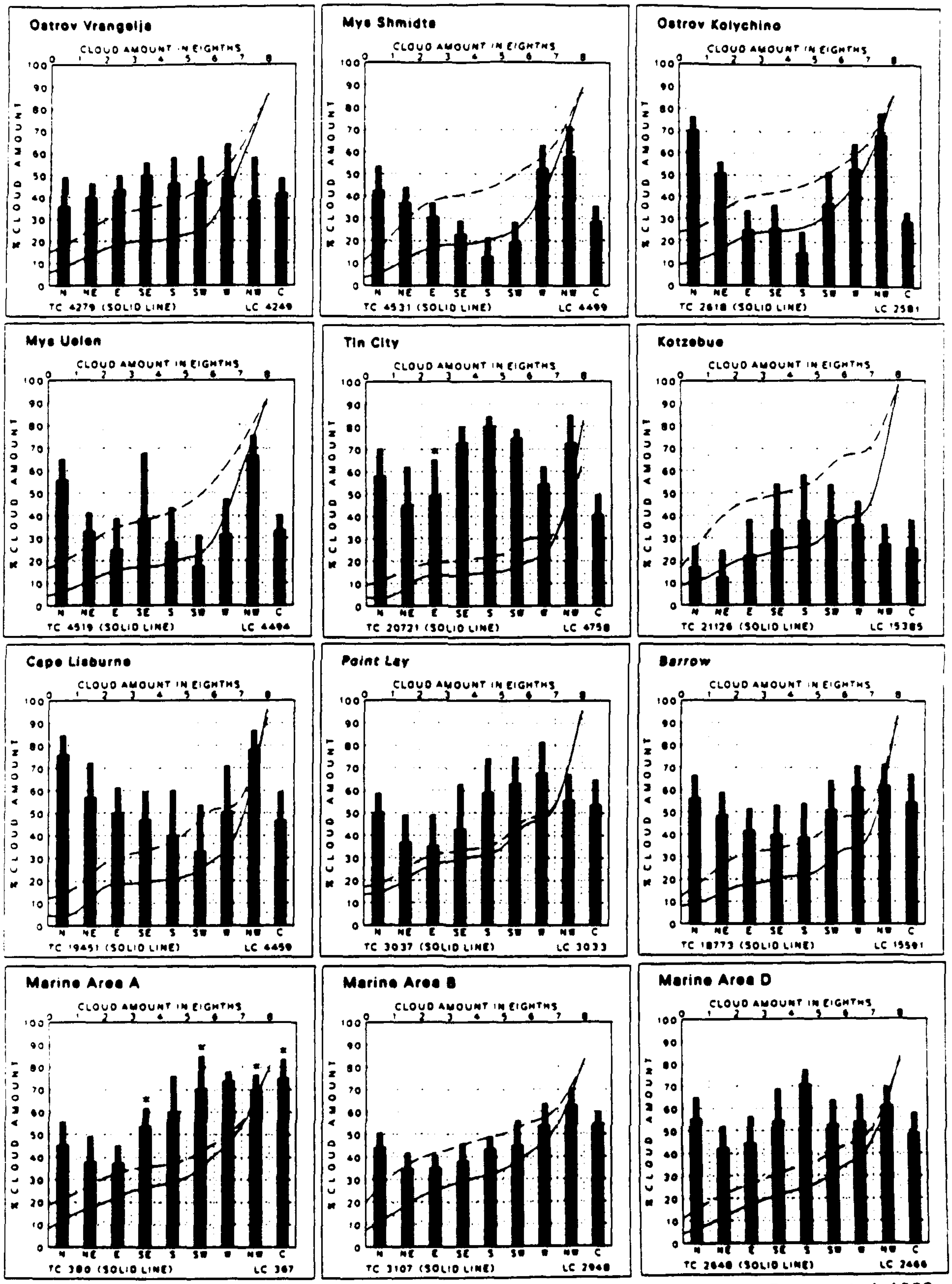


June

After Brower et al. 1988

Figure 32f

Cloud Cover/Wind Direction

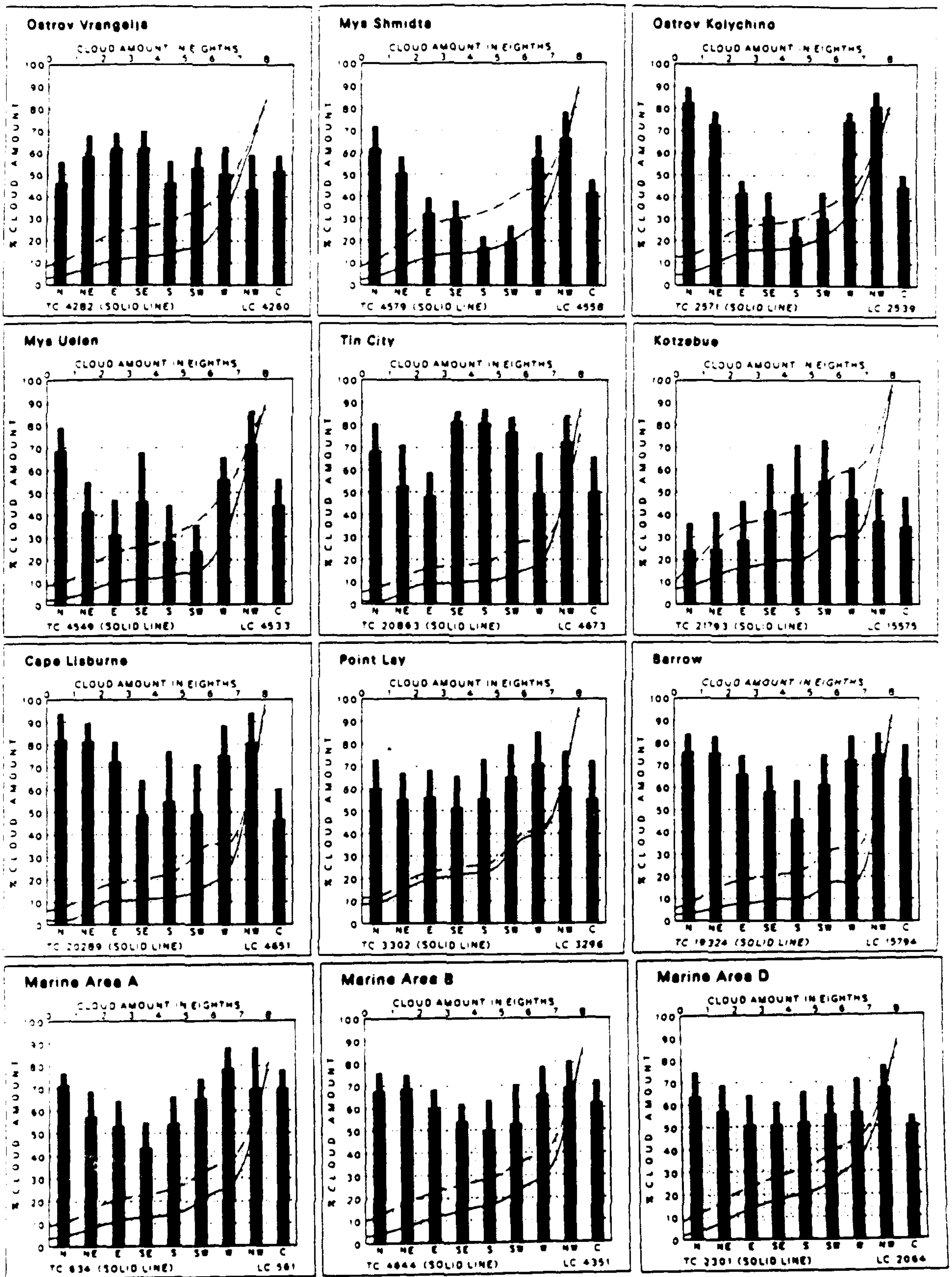


July

After Brower et al. 1988

Figure 32g

Cloud Cover/Wind Direction

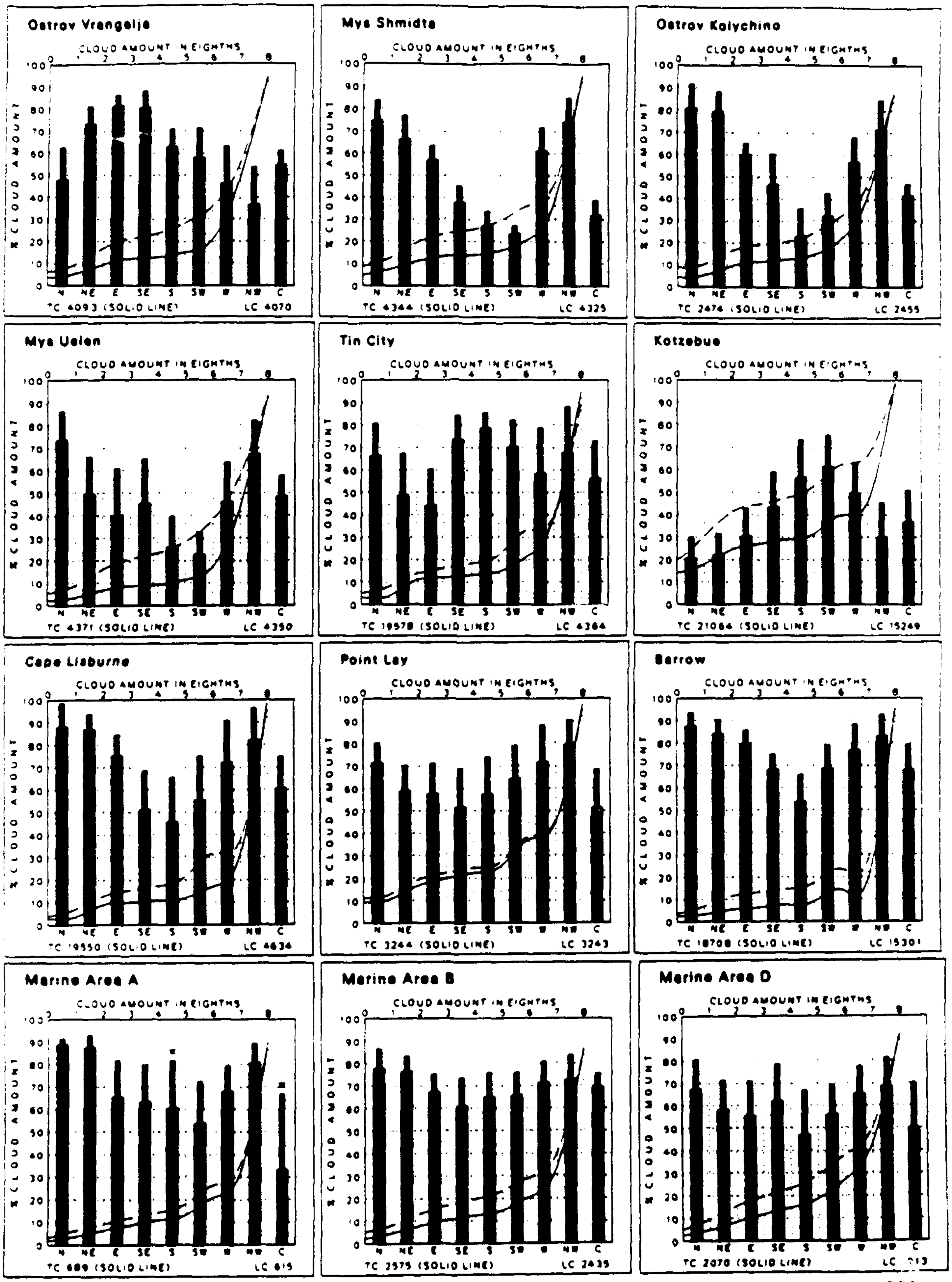


August

After Brower et al. 1988

Figure 32h

Cloud Cover/Wind Direction

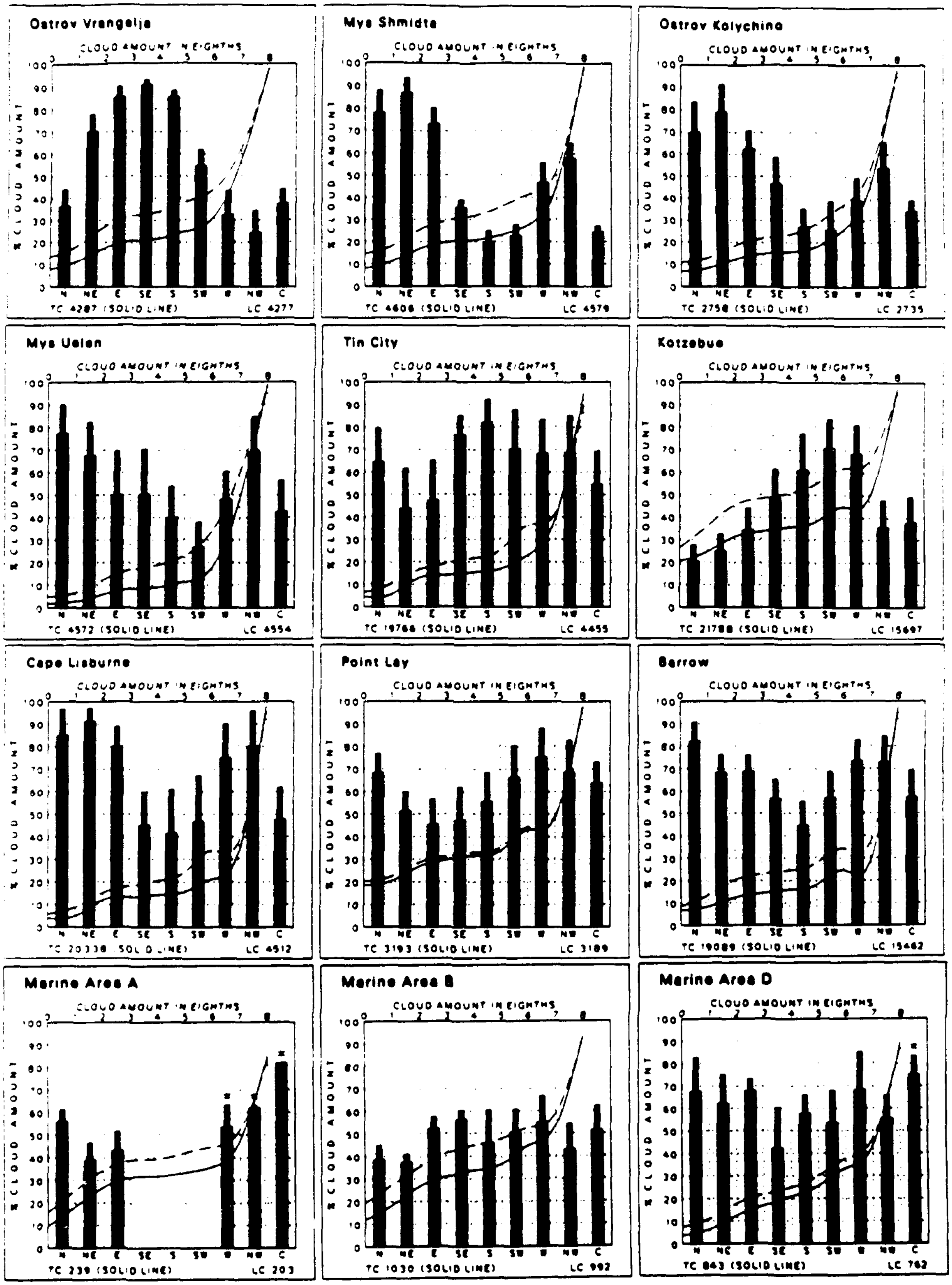


September

After Brower et al. 198

Figure 32i

Cloud Cover/Wind Direction

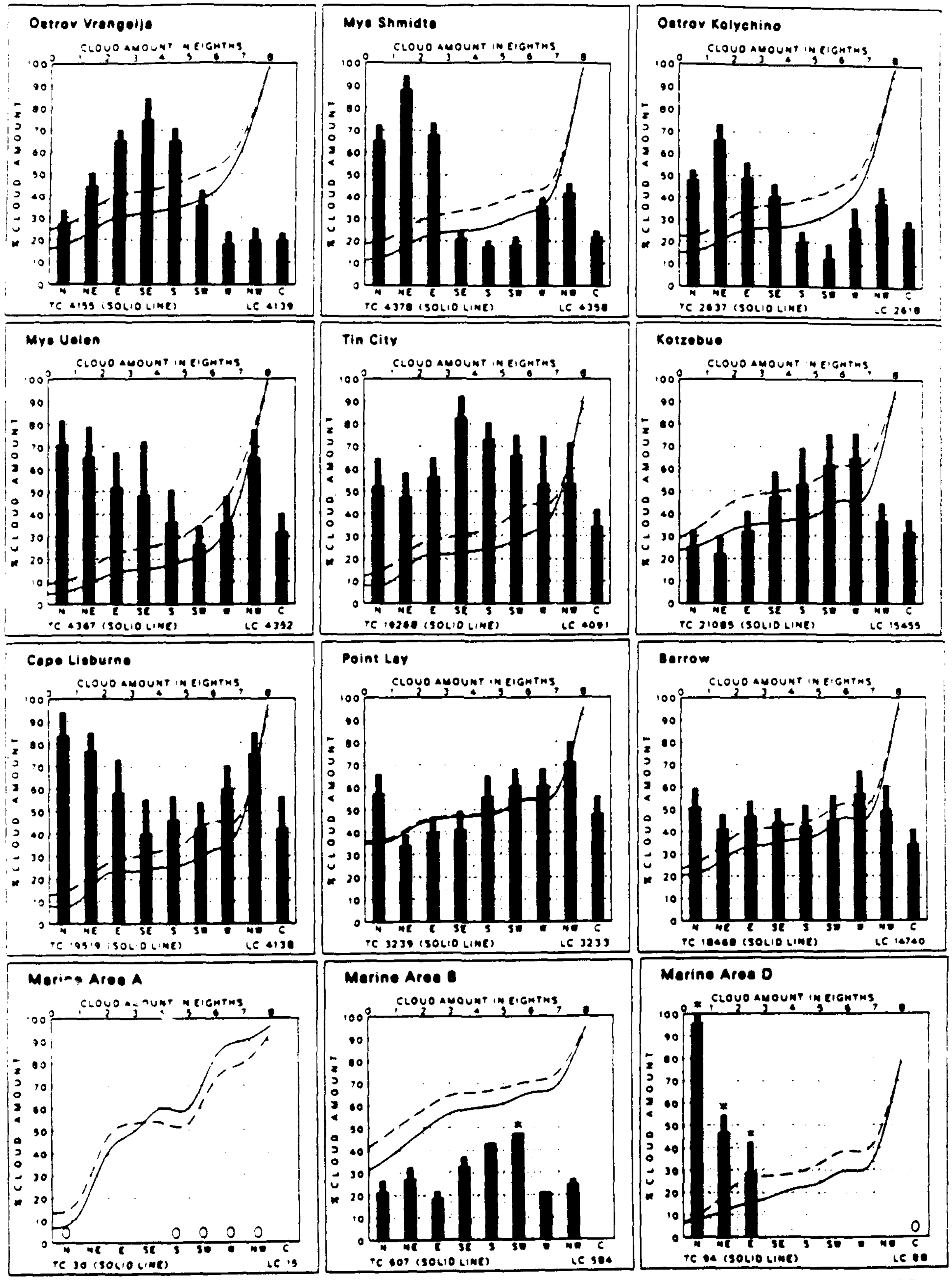


October

After Brower et al. 1988

Figure 32j

Cloud Cover/Wind Direction

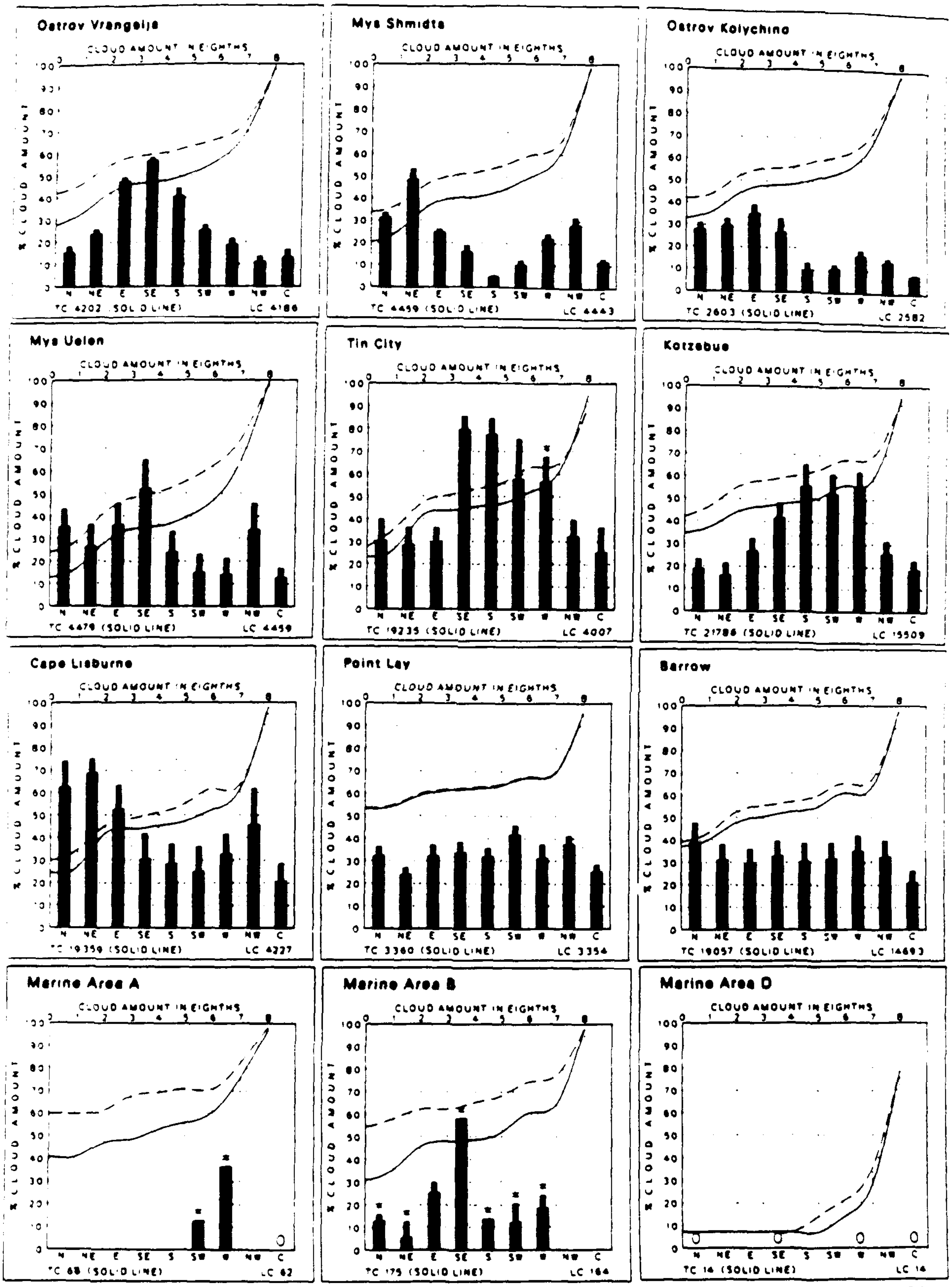


November

After Brower et al. 1988

Figure 32k

Cloud Cover/Wind Direction



After Brower et al. 1988

December

Figure 32l

ICE FORMATION AND DRIFT

INTRODUCTION

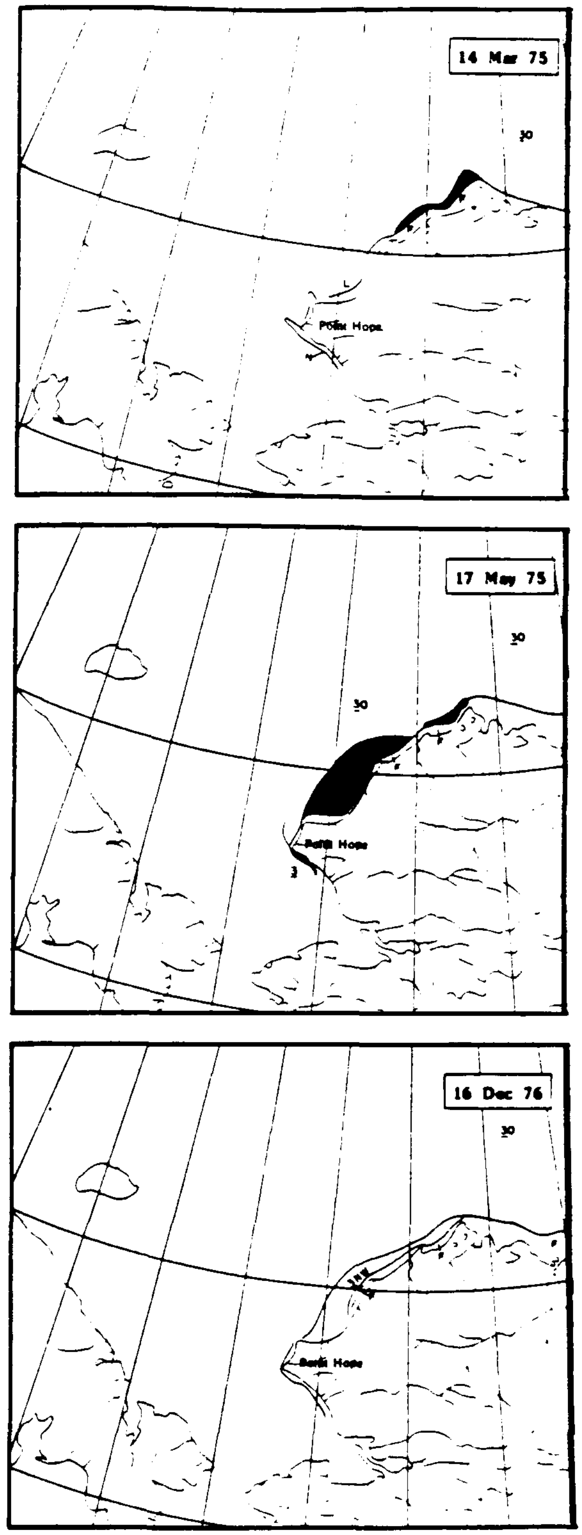
The annual cycle of formation and dissipation of sea ice in Alaska waters has widespread effects on a number of phenomena. When the ice forms, the coastal climate changes in character from maritime to continental with much colder temperatures and lower humidities than would be the case if open waters were present. The ice also impedes and even stops water transportation with the possible exception of icebreakers and other specially designed ships. It makes the cleanup of oil spills difficult, if not impossible, by hampering cleanup operations and by trapping oil under the ice. Sea ice also has important effects on the life cycles and migration patterns of living creatures in and near the sea.

The Chukchi Sea can be characterized by extreme ice motion (Thomas and Pritchard, 1979). Open areas can be formed quickly by this motion and then the cold temperatures can form thin, weak ice over it or winds can close the area again rapidly. The general northward flow of water through the Bering Strait is accompanied by a general northward drift of ice (Reynolds and Pease, 1984). Occasional flow reversals (breakouts) occur demonstrating that the drift of ice corresponds with the surface currents and that both flow and ice drift are driven by the overall wind pattern (Coachman et al. 1975). The variability among years of ice transport through the Bering Strait is also extreme and is coupled to surface water transport.

The ice does not follow the flow of water parcels exactly. For instance, when the wind and barotropic current are in the same direction, the ice moves faster than the water. When the wind and barotropic current are from opposing directions, the ice moves slower than the water parcel. In the spring especially, there is a bifurcation in the northward flow of ice which corresponds to the distribution of surface currents (figures 2, 3). Ice passing through the Bering Strait close to Cape Dezhneva tends to follow a path parallel to the Chukotsk coast along the center line of the 50m+ deep trough extending in the direction of Wrangel Island (Reynolds and Pease 1984). Ice passing through the Bering Strait between Little Diomede Island and Cape prince of Wales tends to follow the 30-m isobath paralleling the Alaskan coast from Point Hope to Barrow Canyon (figures 1, 2).

The Chukchi Sea remains virtually ice-covered from the beginning of December into mid-May, with the exception of a relatively wide shore lead that may develop seaward of the shorefast ice along the northwest coast (figure 33). This feature is particularly prevalent from Point Lay to Point Barrow during periods of strong easterly winds. Around mid-May the seasonal disintegration of the ice cover begins as shorefast ice and thin ice decay and loosen along the northwest coast and in the interior of Kotzebue Sound (Webster 1982). It is not until the beginning of July that there is a significant reduction in the probability of ice cover in the southern Chukchi Sea. Ice generally stays near the coast at Point Barrow into late July and early August. The length of the navigation season around Point Barrow to Prudhoe Bay varies from not open at all in 1975 to open 99+ days in 1958. The median date for the initial opening of the route to Prudhoe Bay is August 2 and dates of openings varied from July 19 in three years to September 13 in 1955 (U.S. Navy 1986).

Recurring Leads and Polynyas



KEY

- Large black areas indicate open water to 1/10 ice cover
- Thin line leading into thicker line indicates a crack/lead
- Single thin line indicates division between ice cover categories
- L Indicates an open lead and is inserted in some cases where lead is not obvious

F Fast ice	1 2/10-5/10 ice cover
N New ice	2 6/10-7/10 ice cover
O Old ice	2+ 8/10 ice cover
M Multi-year ice	3 9/10-10/10 ice cover
W Grey-white ice	

Source: Stirling and Cleator 1981.

Figure 33

ICE EDGE LOCATION AND FIVE-TENTHS ICE CONCENTRATION

Semi-monthly information on the probabilities of the locations of the ice edge and the five-tenths ice concentration boundary are presented in figures 34a-34p and figures 35a-35o, respectively, from source information covering a 28-year period from 1953 to 1981 (Webster 1981, 1982), as displayed in LaBelle et al. (1983). The ice edge is the southernmost extent of sea ice coverage of any concentration at any given time. The five-tenths ice concentration boundary is the ice concentration above which ice breaking vessels are needed for navigation. Ice concentration, however, implies nothing about ice thickness or strength.

The separation between the ice edge and the five-tenths ice concentration boundary is greatest during the period that the ice edge is retreating northward, during the late spring and summer months. During periods when the ice edge is either stationary or advancing southward during the fall, winter, or early spring, the two boundaries are coincident.

ICE CONCENTRATION

Monthly ice concentrations from data for the years 1954 to 1977, adapted from Potocsky (1975) and Walsh (1978, 1979), as displayed in LaBelle et al. (1983), are presented in figures 36a-36l. The estimated ice edge shown in the maps is the mean location of the ice edge over the period of time covered. This means that you could expect the ice edge to be north of the line 50% of the time, and south of the line 50% of the time.

Ice concentrations are plotted in categories (in tenths of ice coverage) of 1-2, 3-4, 5-6, 7-8, and 9-10.

ICE FLOE DISTRIBUTION

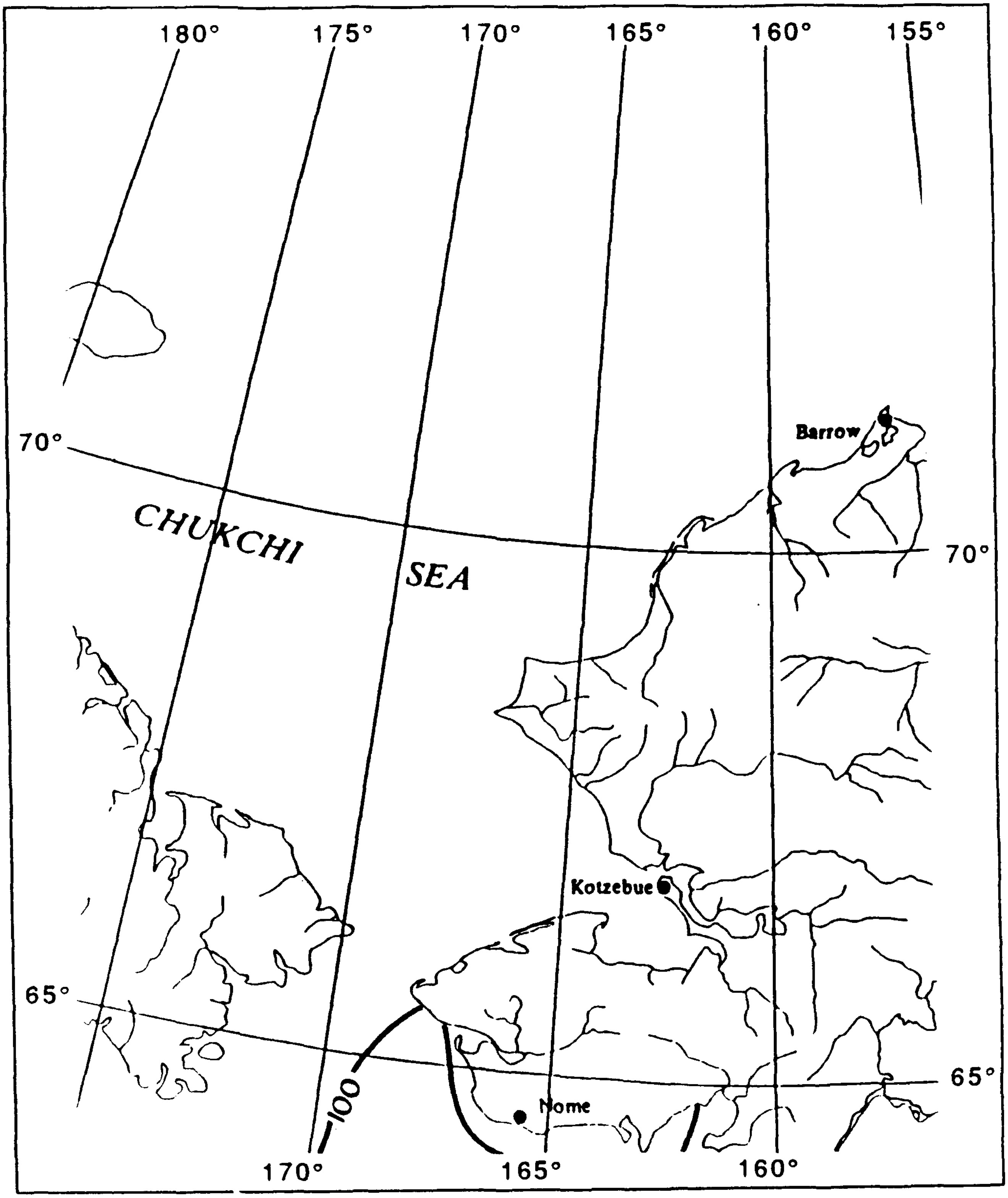
Figures 37a-37x show semi-monthly profiles of floes that are from 500m (1640 ft) to greater than 10km (16mi) in diameter (i.e., big, vast, and giant floes), as displayed in LaBelle et al. (1983). This information was derived from Potocsky (1975), using data from 1954 to 1970. These data do not imply anything about ice thickness. Dotted lines outline limits of observations and cross hatched areas denote where floe size was undetermined.

CALCULATED ICE THICKNESS

Ice thicknesses (in cm), as calculated from normal freezing degree day accumulations, are presented in figures 38a-38h. The upper figure corresponds to thickness in the middle of the month; the lower at the end of the month. Data from 1922 to 1984 were used. Ice thickness data shown apply to level first-year ice formed in-situ with no snow cover. Actual ice thicknesses for any given season will vary depending on actual air temperatures, the amount of snow cover, and underlying sea surface currents. Generally, as snow cover increases, forming an insulating cover over the ice, ice growth decreases.

In order to provide as great an area coverage as possible, ice thicknesses were calculated for the nearest reporting weather stations.

Probability in Percent of the Ice Edge Location

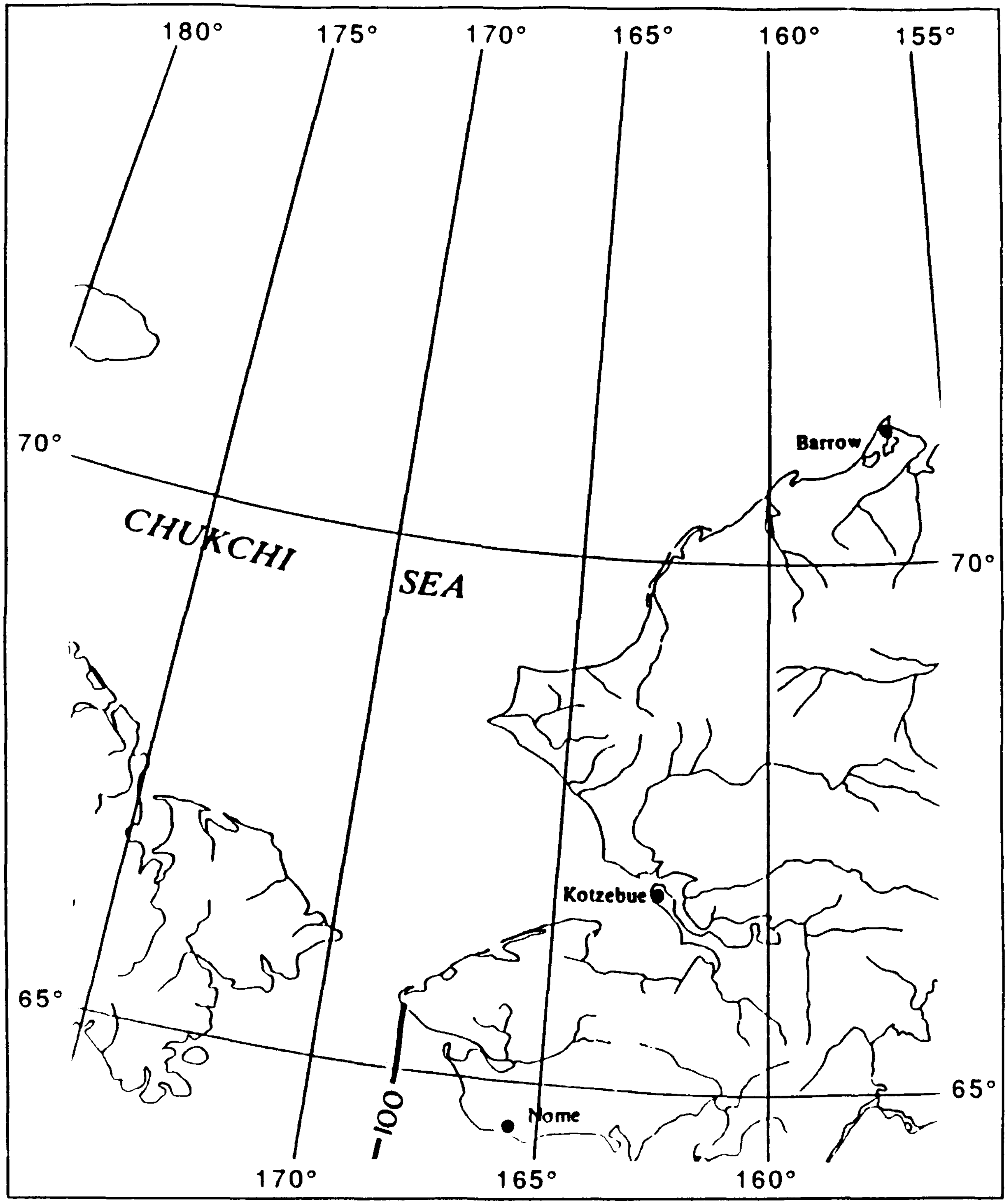


May 1

After LaBelle et al. 1983

Figure 34a

Probability in Percent of the Ice Edge Location

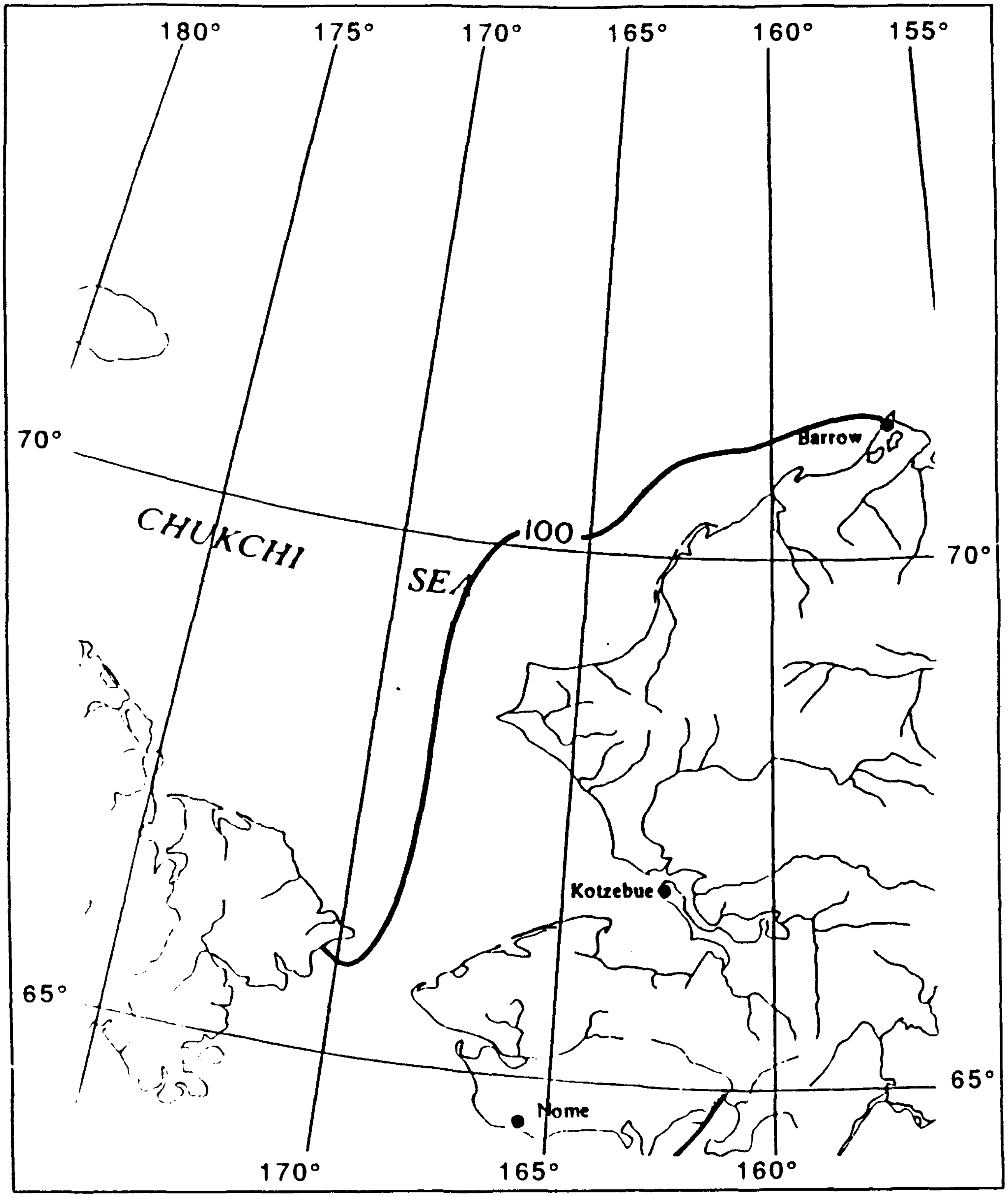


May 15

After LaBelle et al. 1983

Figure 34b

Probability in Percent of the Ice Edge Location

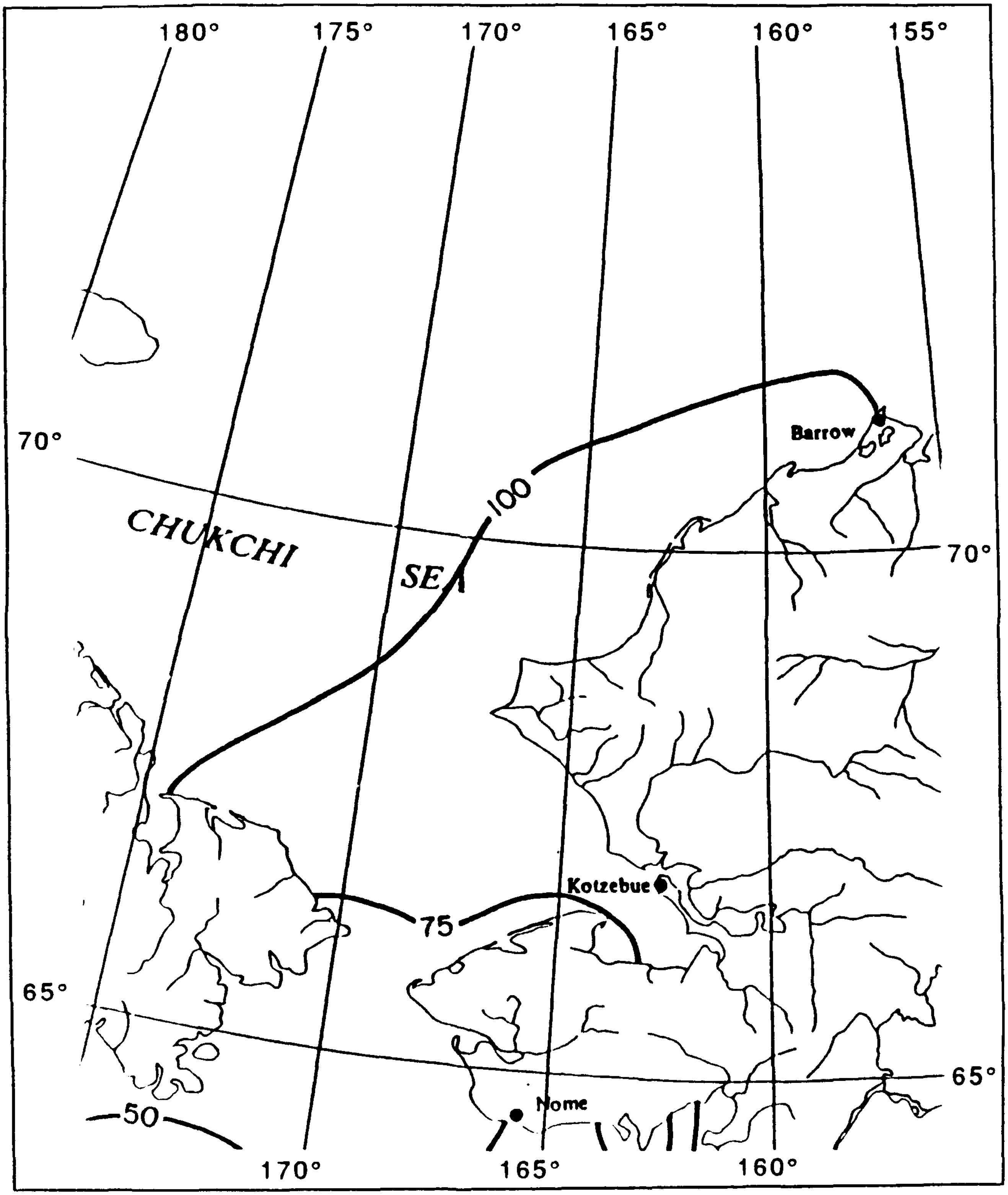


June 1

After LaBelle et al. 1983

Figure 34c

Probability in Percent of the Ice Edge Location

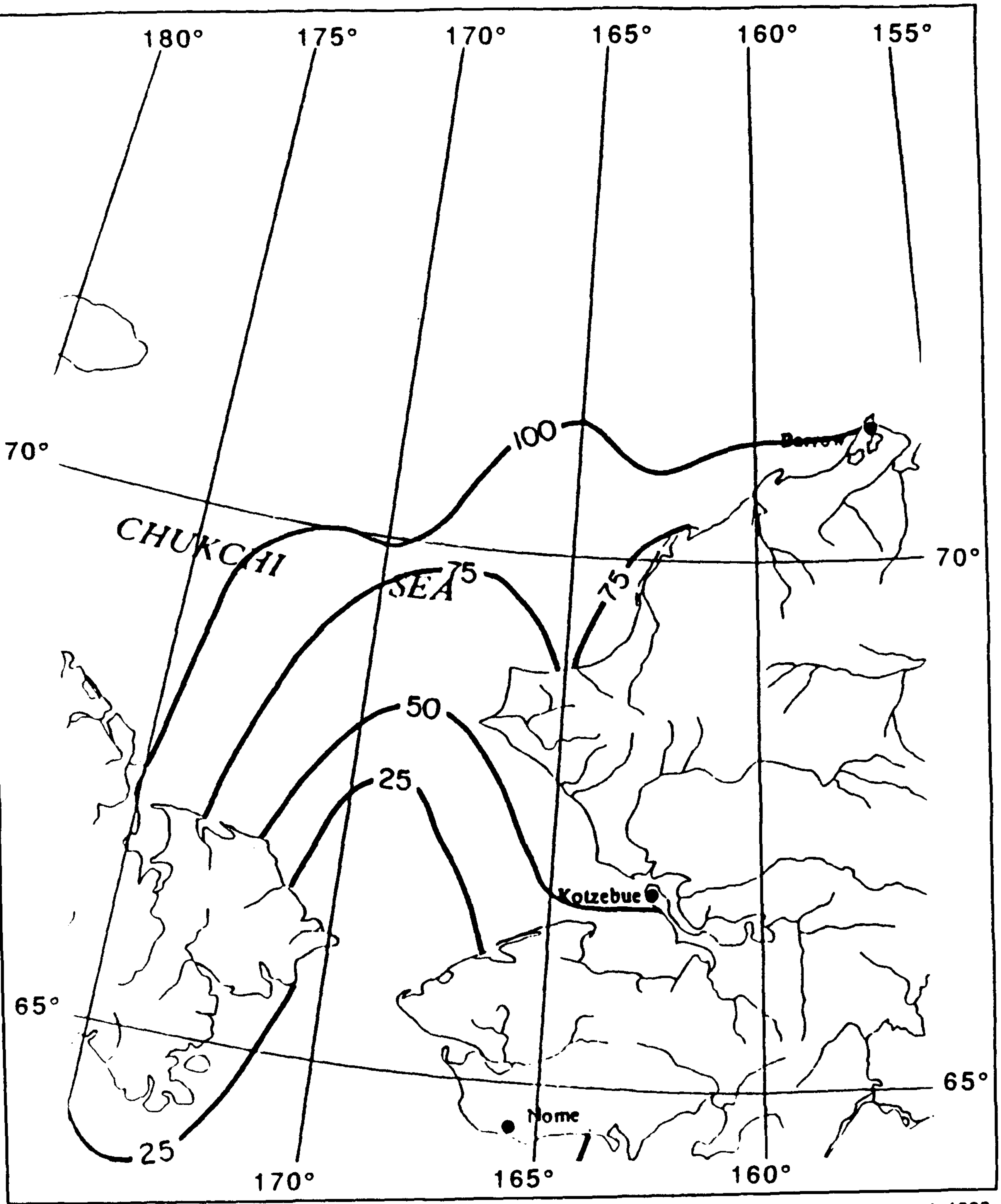


June 15

After LaBelle et al. 1983

Figure 34d

Probability in Percent of the Ice Edge Location

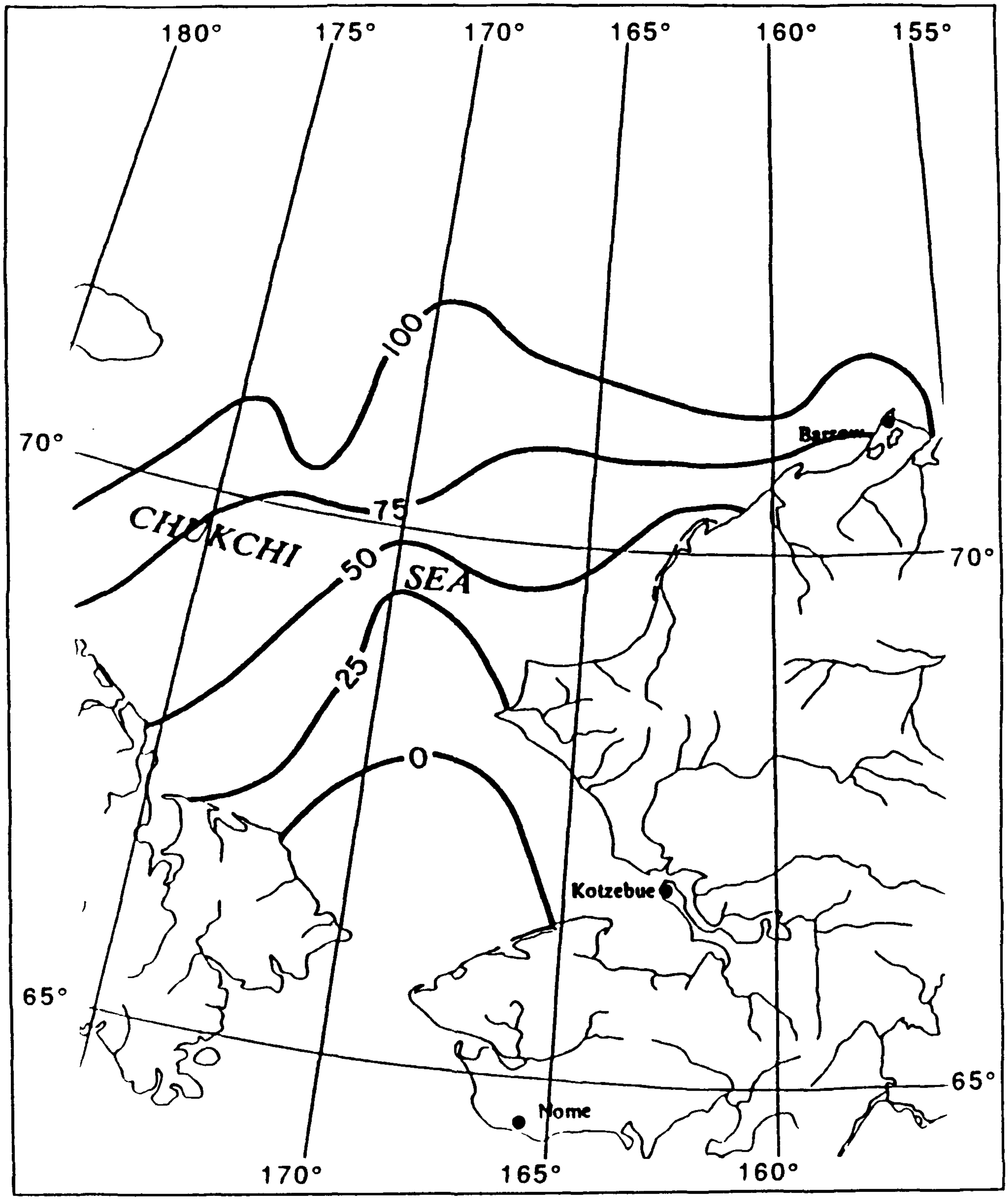


July 1

After LaBelle et al. 1983

Figure 34e

Probability in Percent of the Ice Edge Location

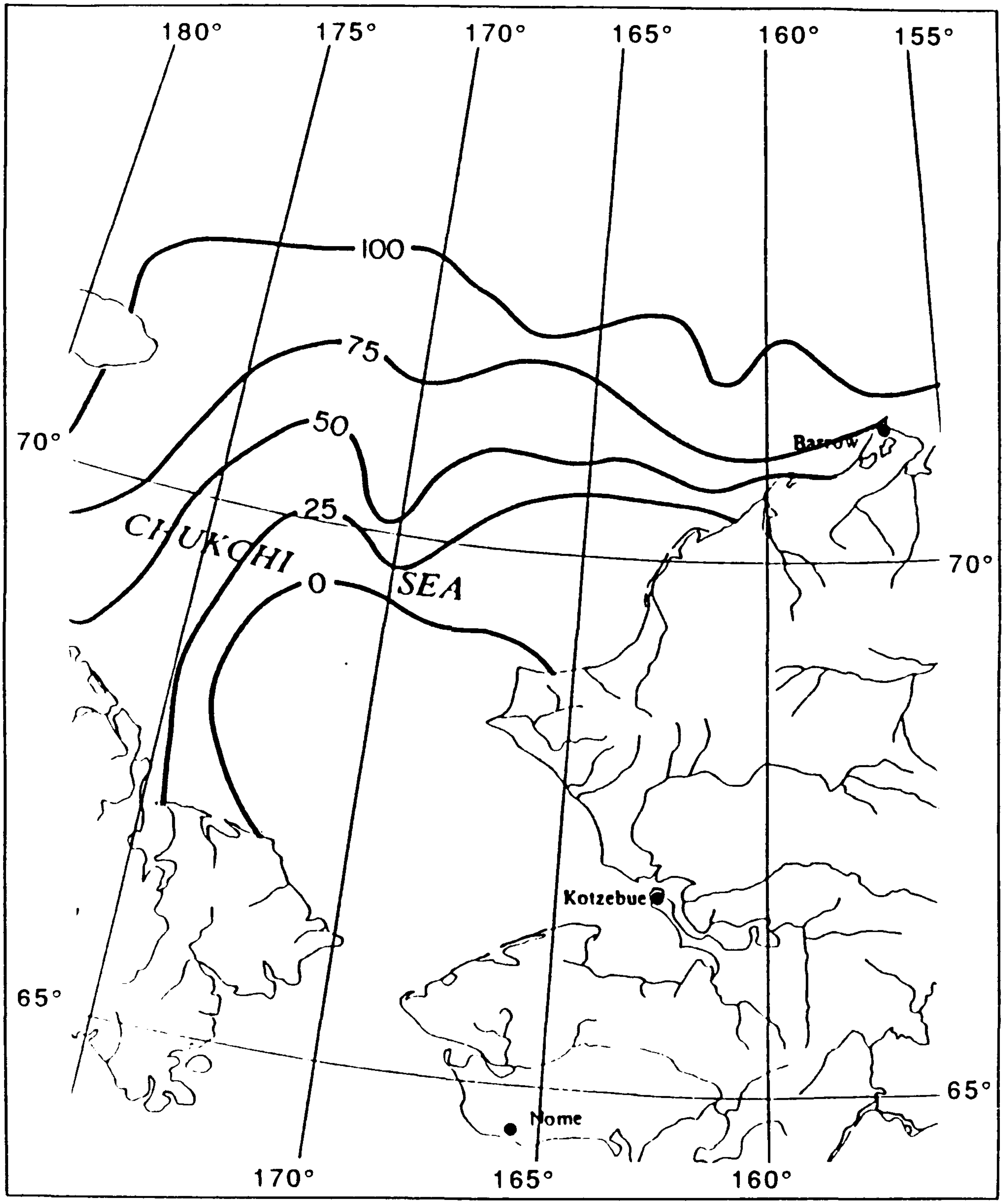


July 15

After LaBelle et al. 1983

Figure 34f

Probability in Percent of the Ice Edge Location

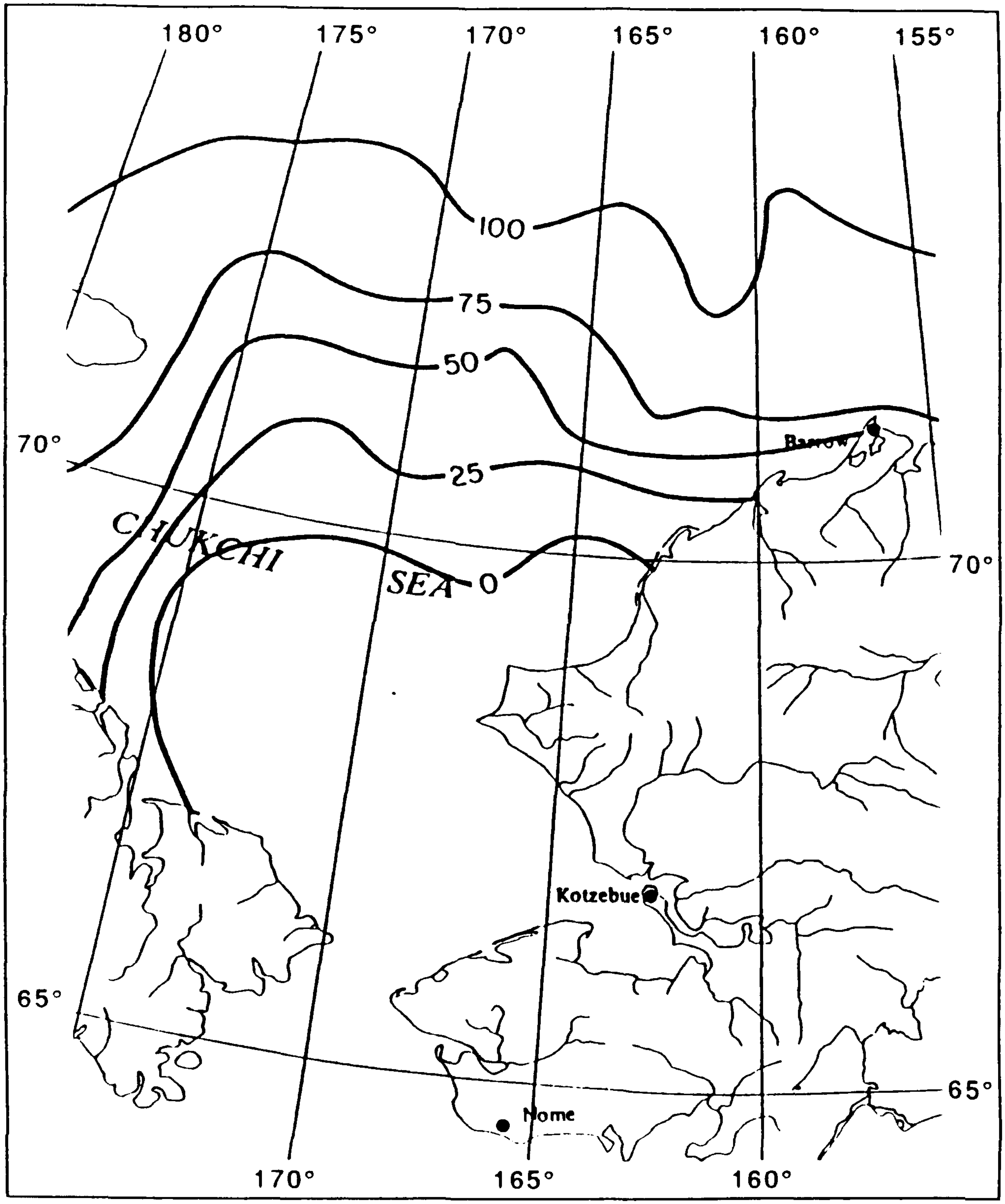


August 1

After LaBelle et al. 1983

Figure 34g

Probability in Percent of the Ice Edge Location

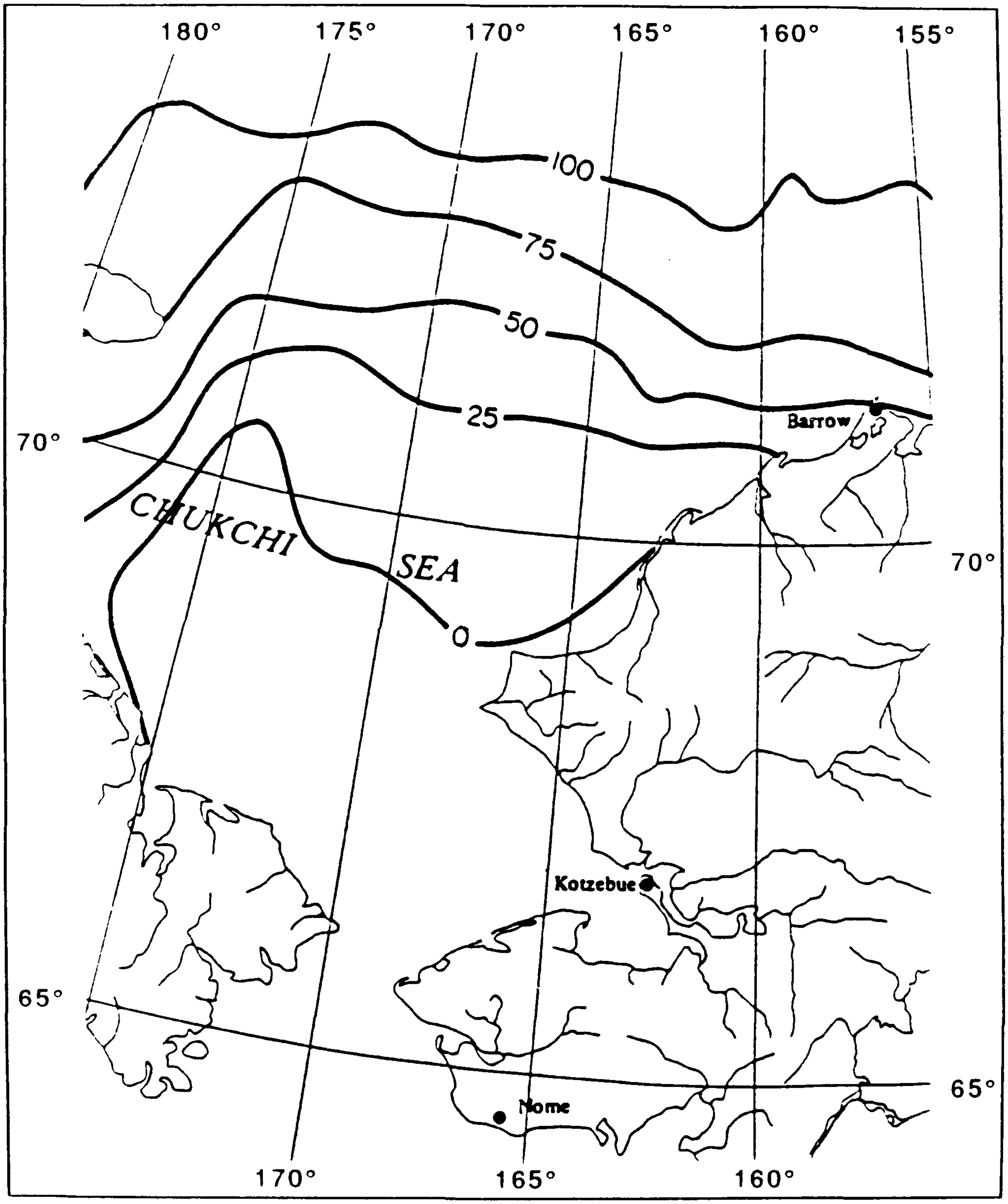


August 15

After LaBelle et al. 1983

Figure 34h

Probability in Percent of the Ice Edge Location

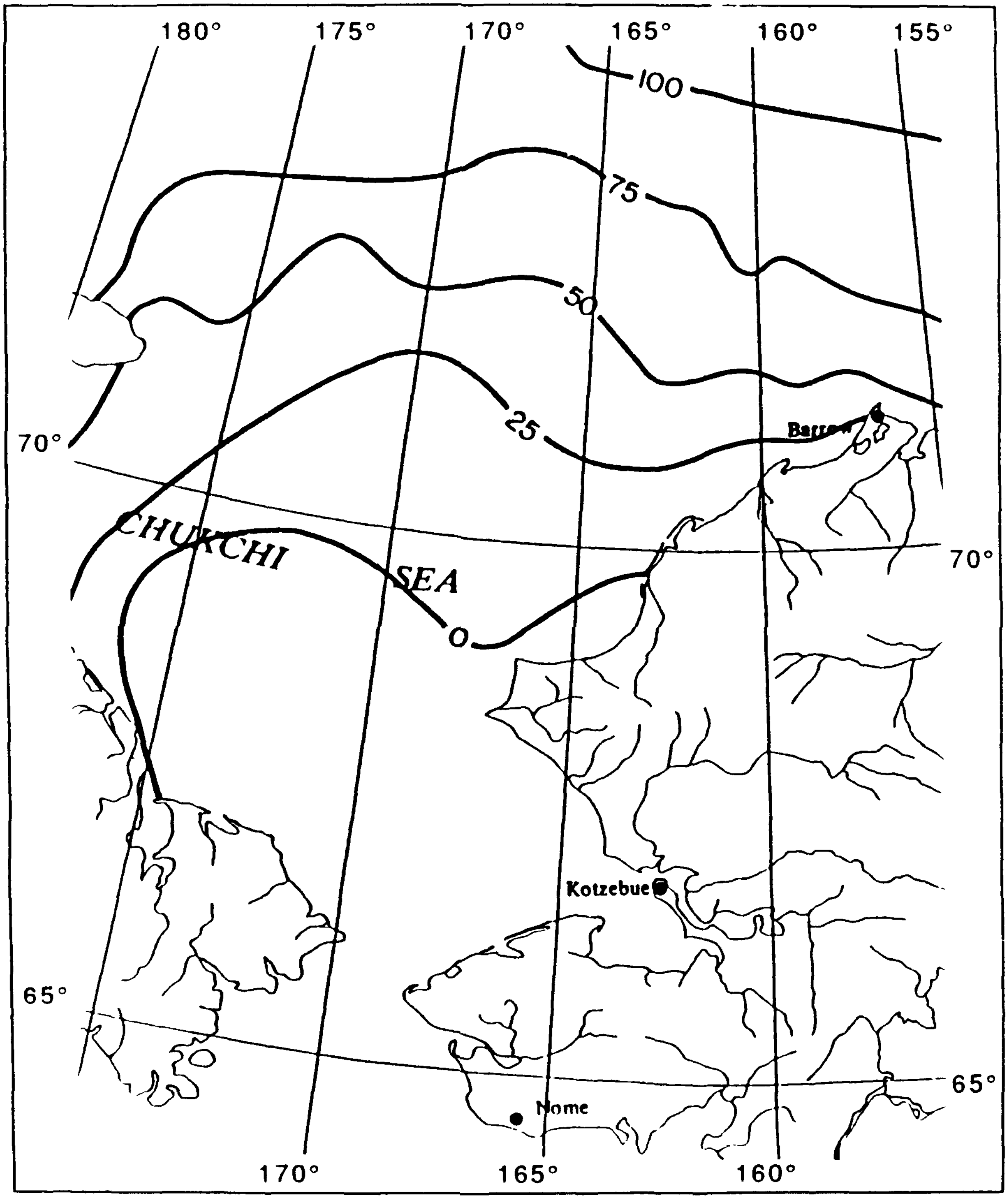


September 1

After LaBelle et al. 1983

Figure 34i

Probability in Percent of the Ice Edge Location

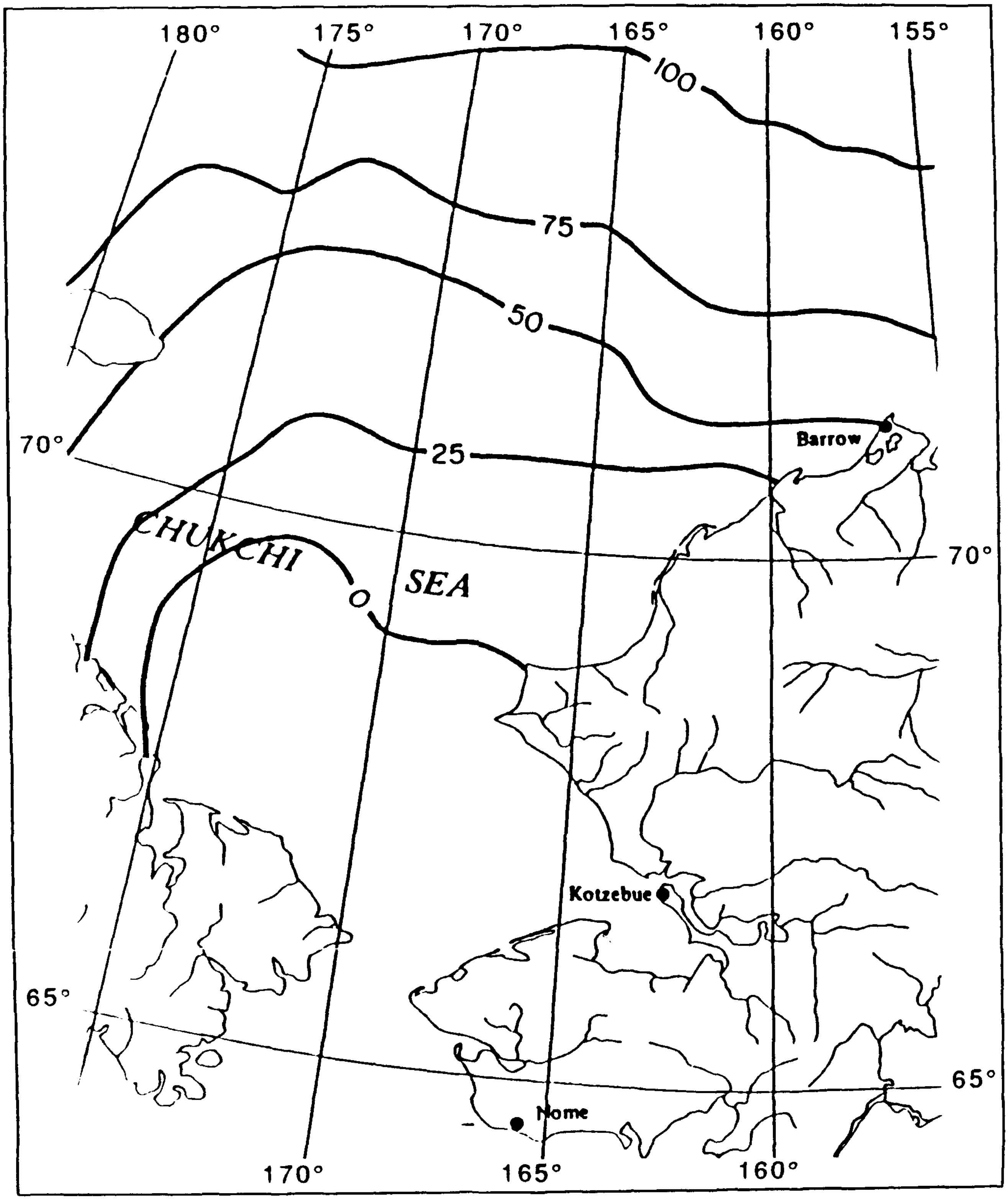


September 15

After LaBelle et al. 1983

Figure 34j

Probability in Percent of the Ice Edge Location

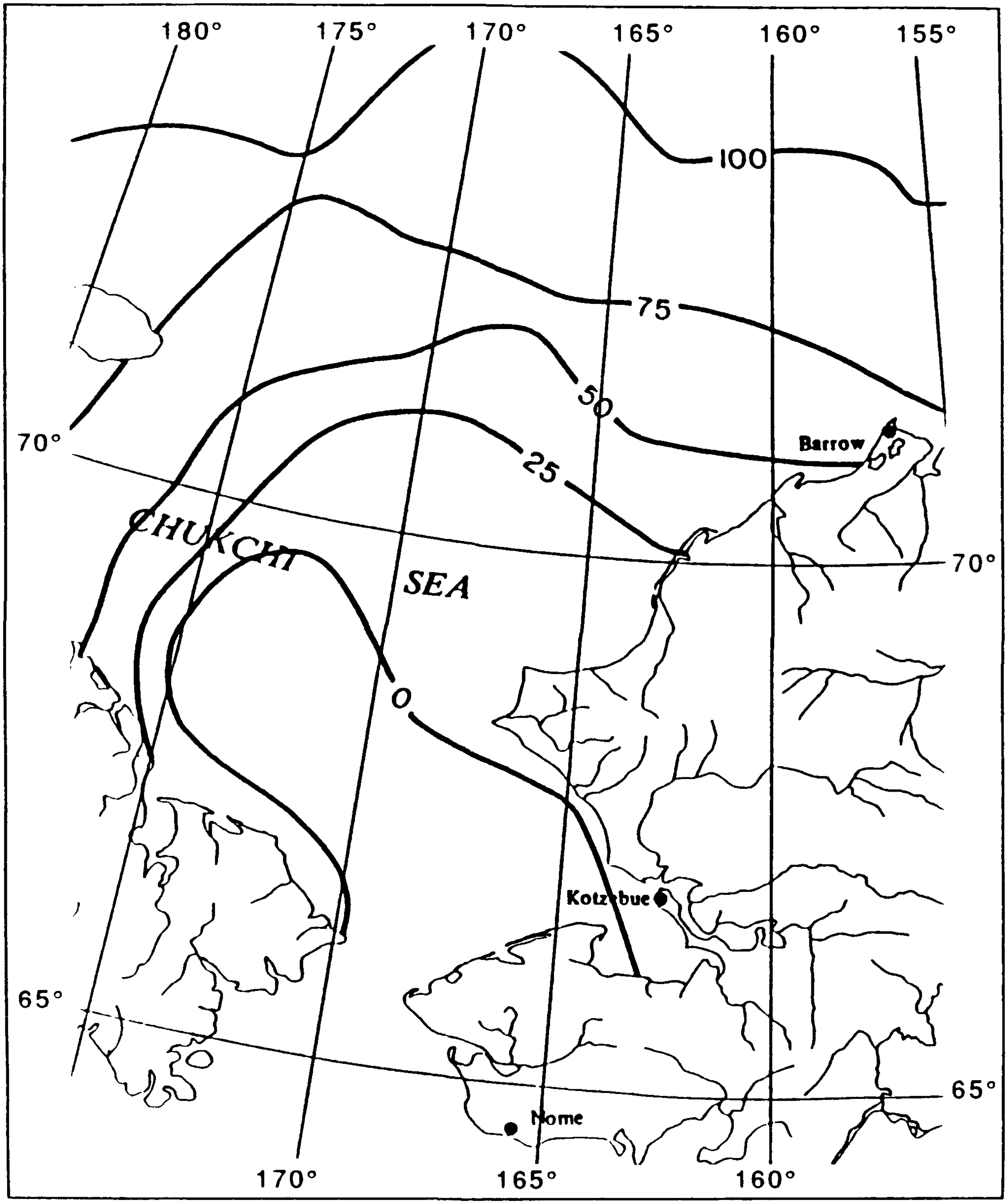


October 1

After LaBelle et al. 1983

Figure 34k

Probability in Percent of the Ice Edge Location

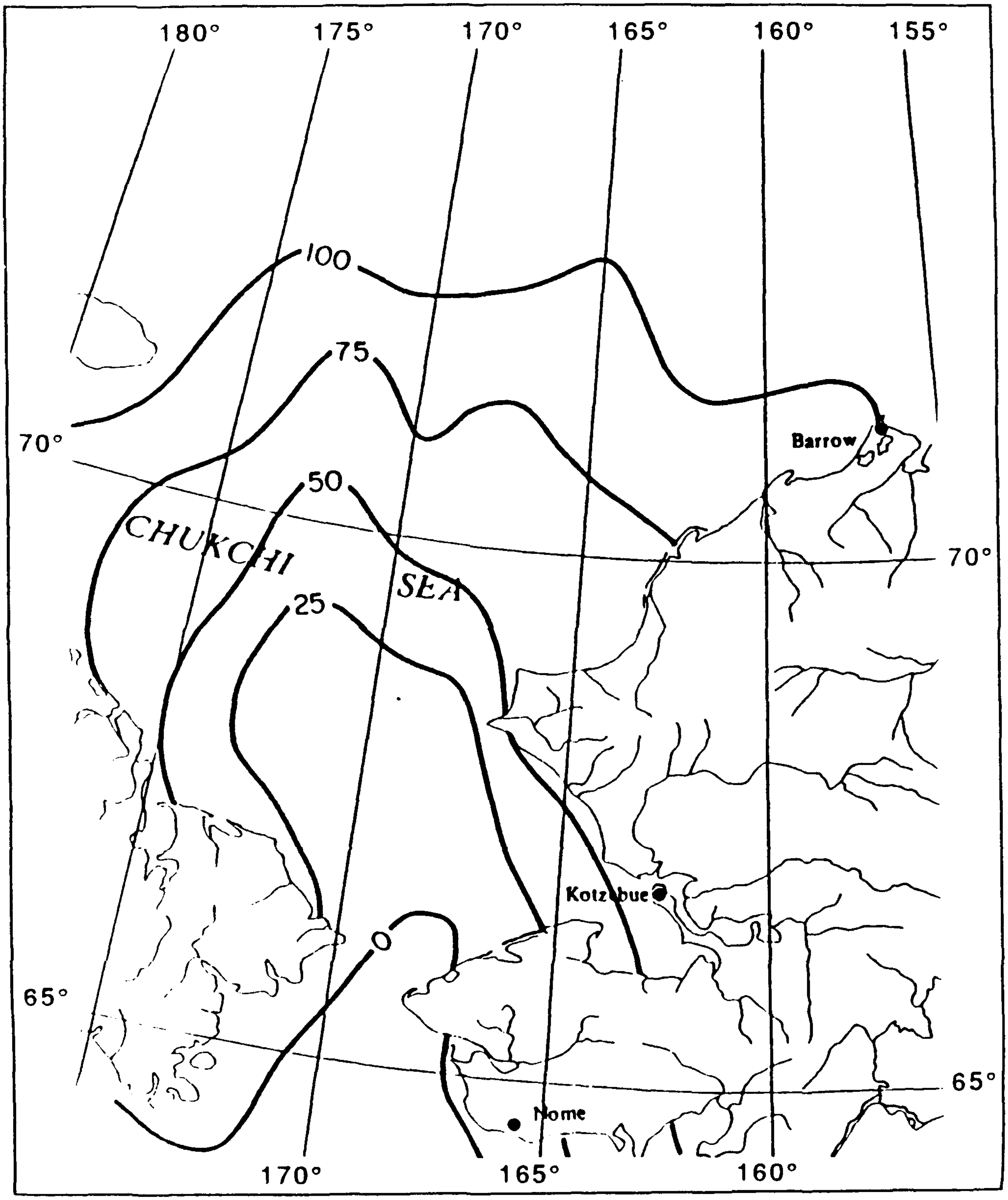


October 15

After LaBelle et al. 1983

Figure 241

Probability in Percent of the Ice Edge Location

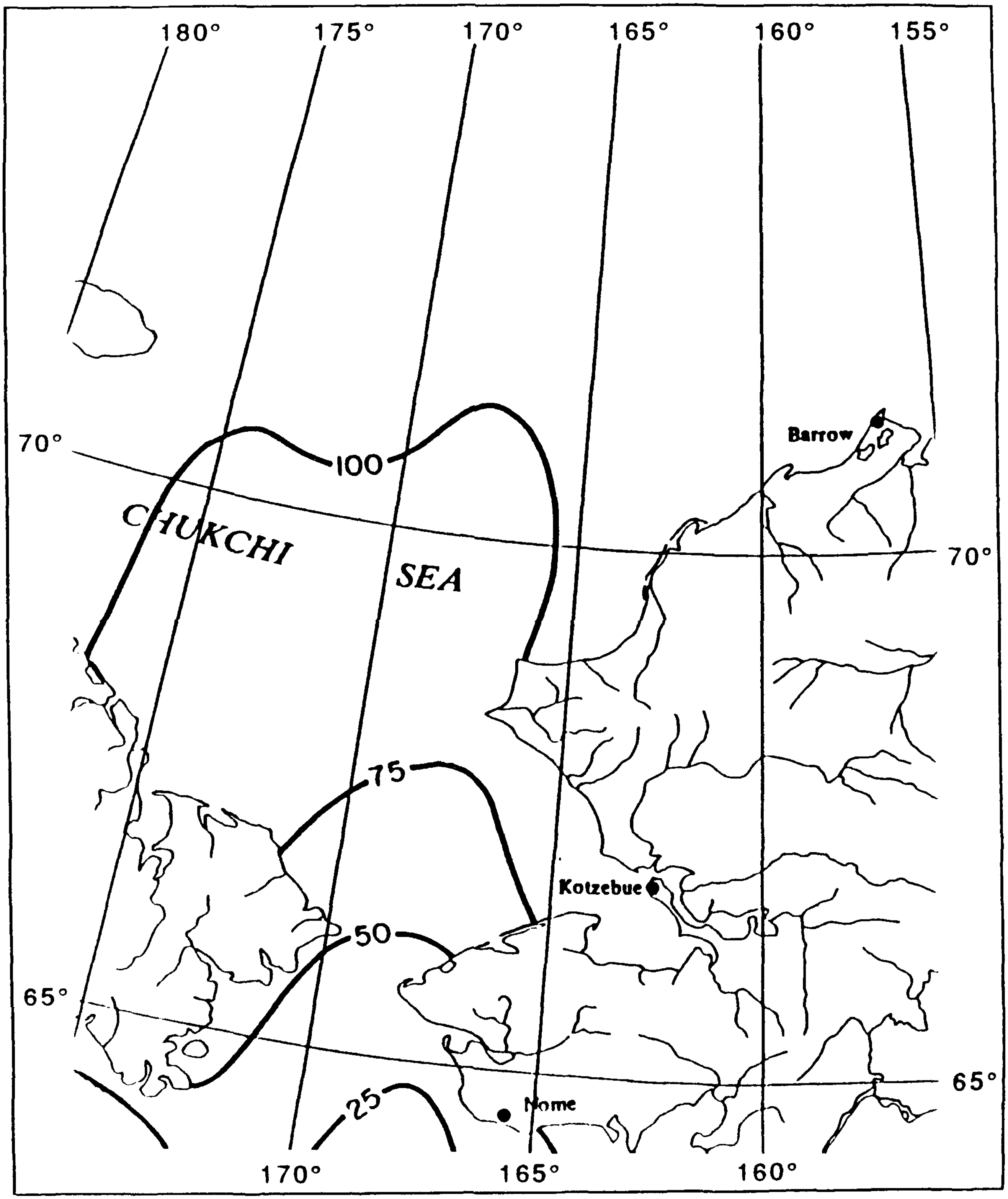


November 1

After LaBelle et al. 1983

Figure 34m

Probability in Percent of the Ice Edge Location

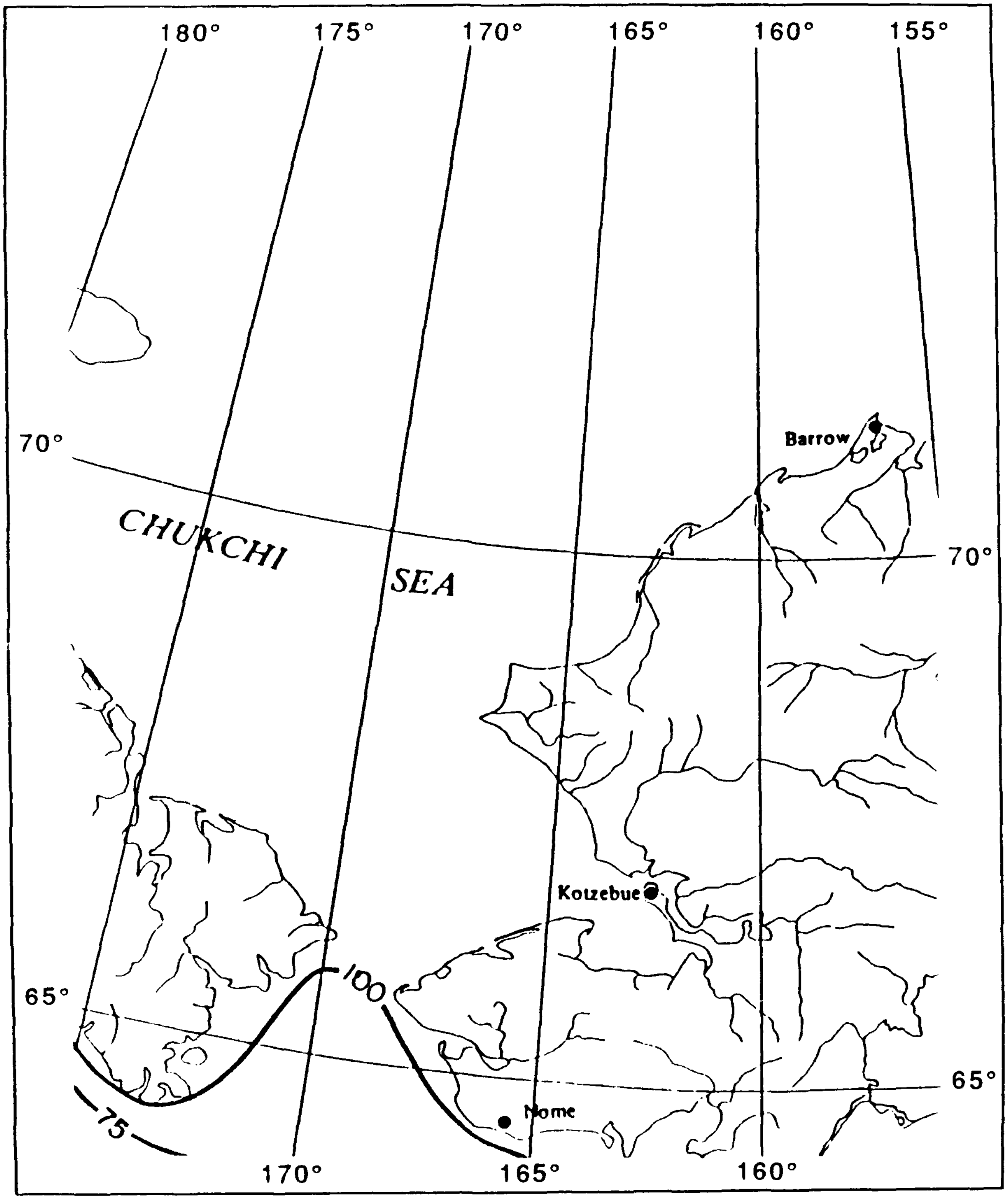


November 15

After LaBelle et al. 1983

Figure 34n

Probability in Percent of the Ice Edge Location

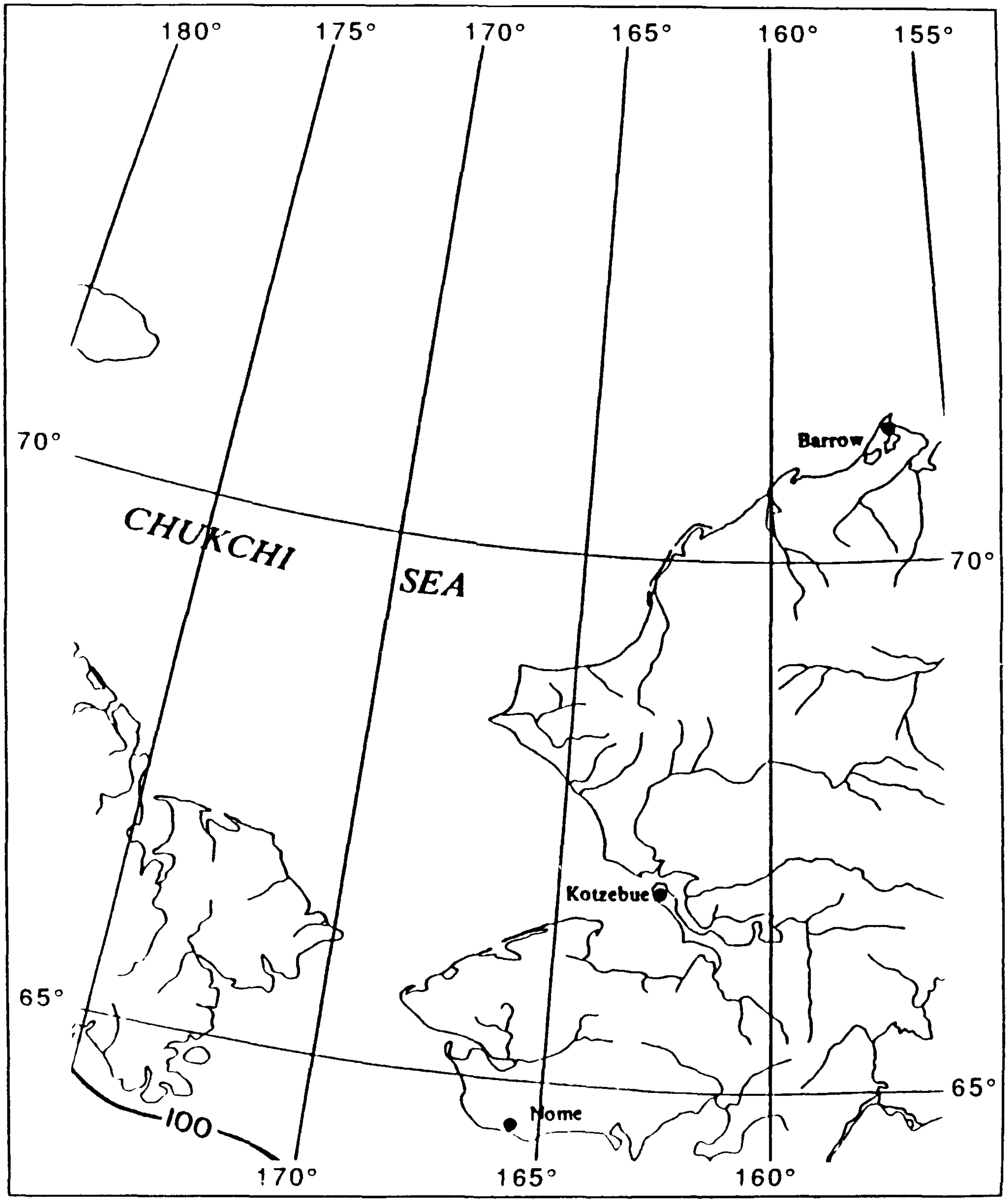


December 1

After LaBelle et al. 1983

Figure 34o

Probability in Percent of the Ice Edge Location

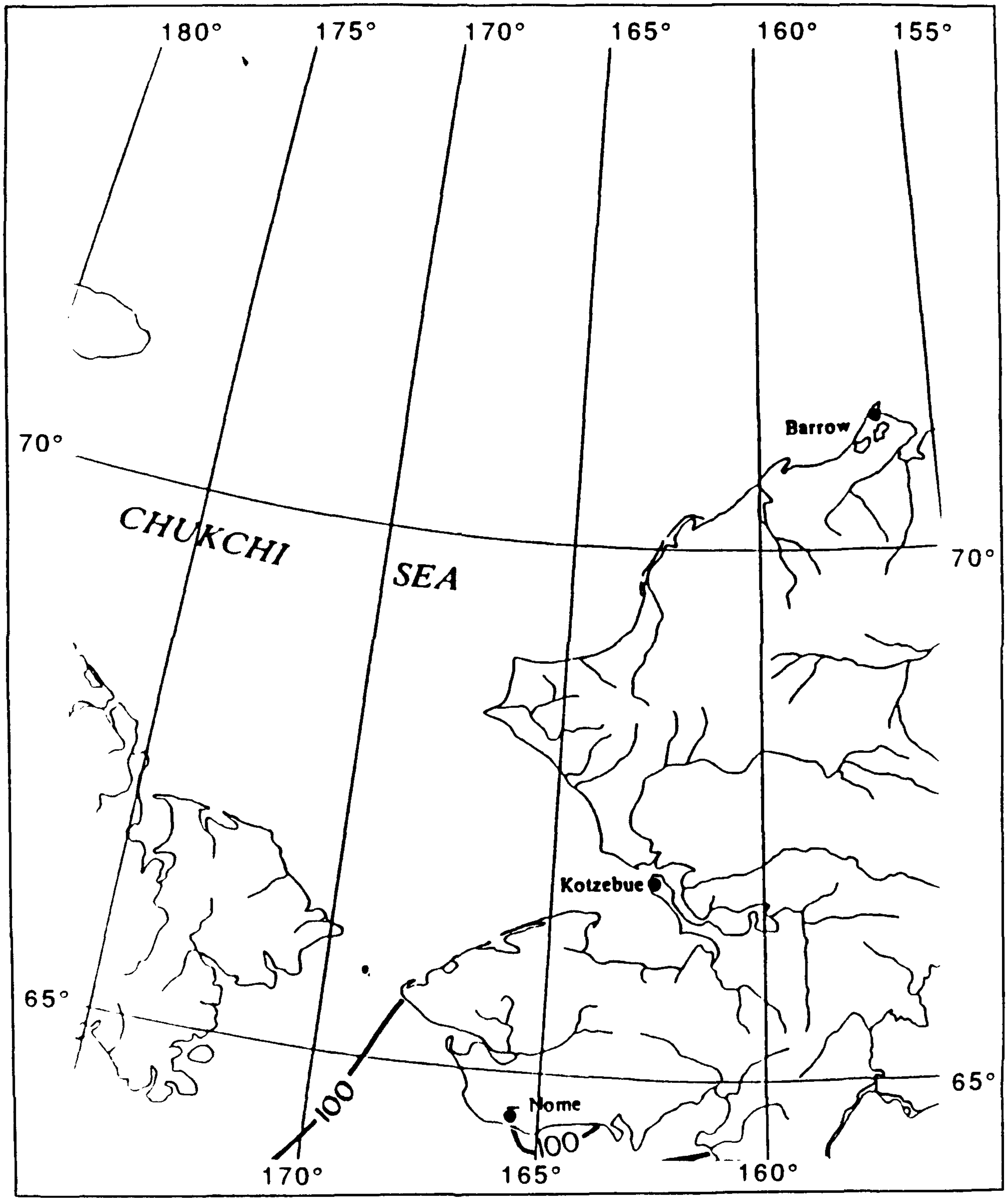


December 15

After LaBelle et al. 1983

Figure 34p

Probabilities in Percent of the Five-Tenths Ice Concentration Boundary

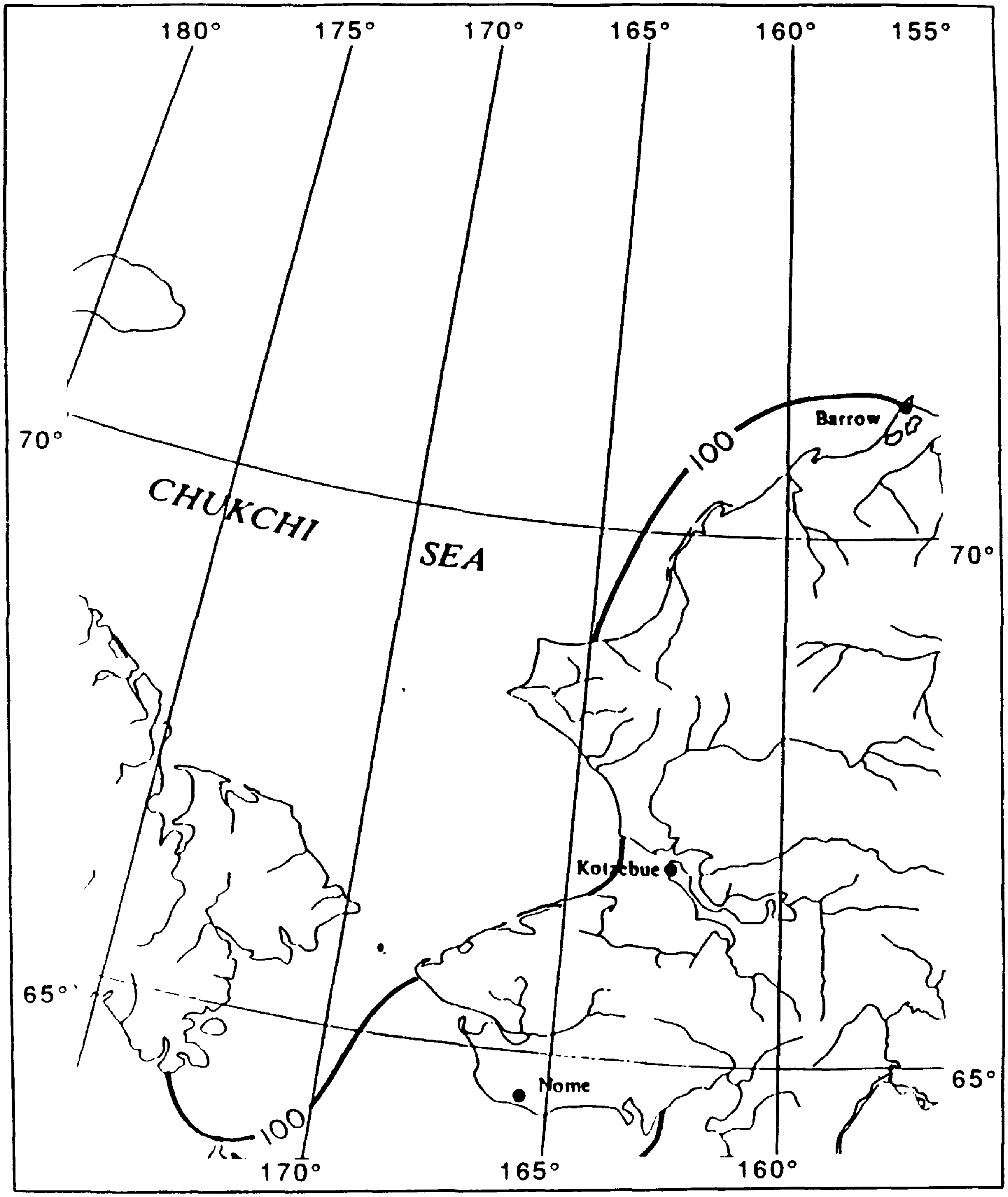


After LaBelle et al. 1983

May 1

Figure 35a

Probabilities in Percent of the Five-Tenths Ice Concentration Boundary

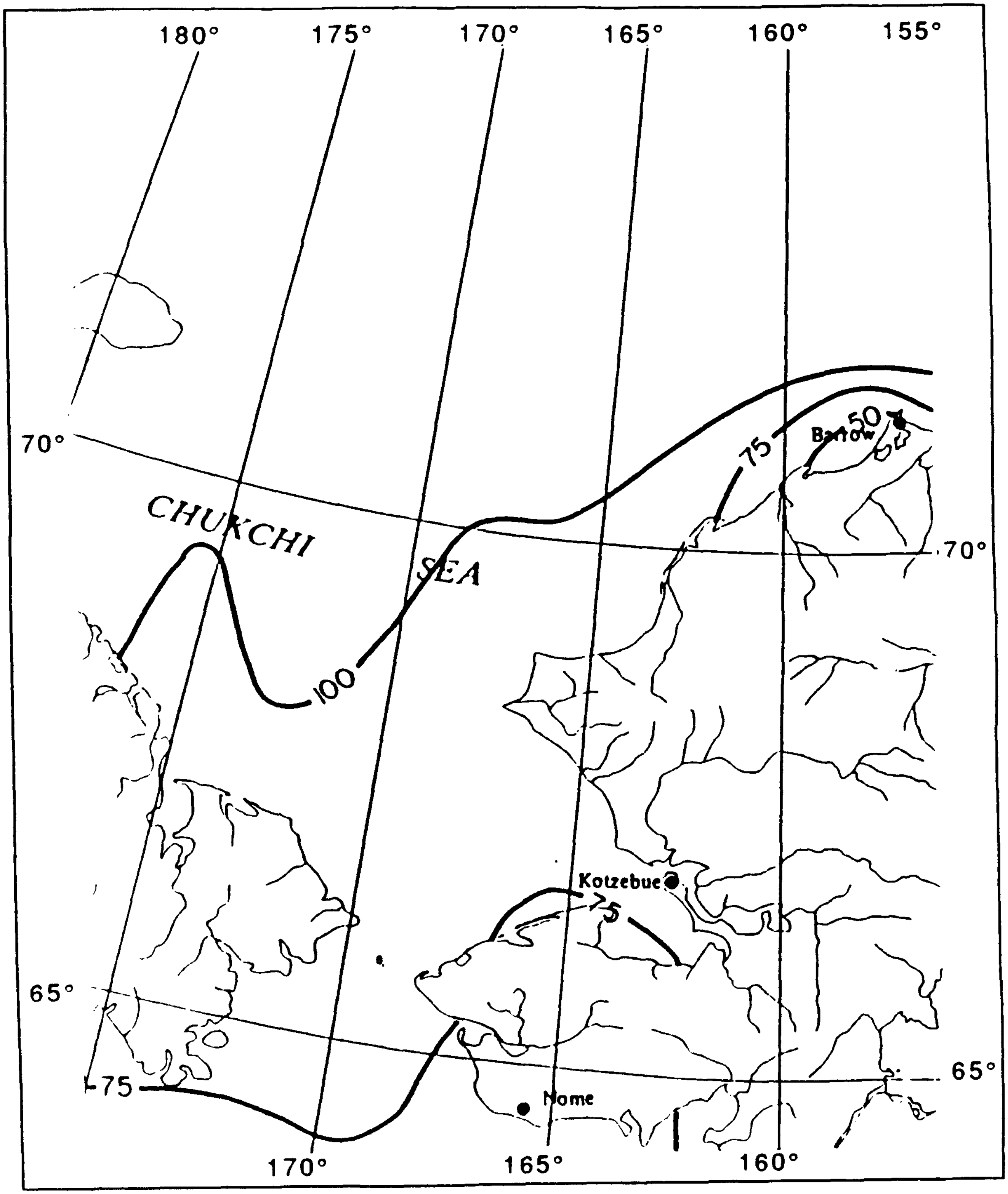


After LaBelle et al. 1983

May 15

Figure 35b

Probabilities in Percent of the Five-Tenths Ice Concentration Boundary

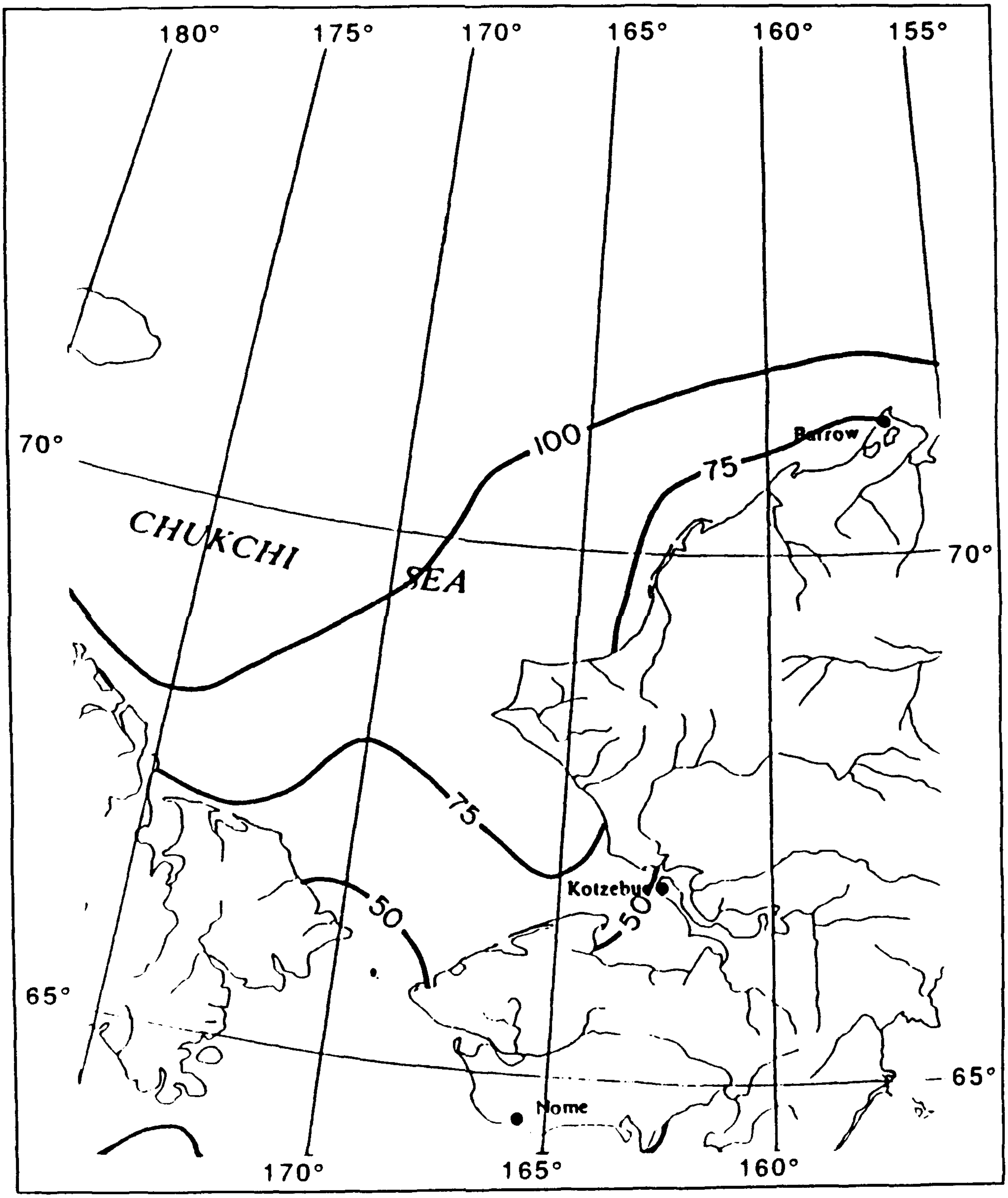


After LaBelle et al. 1983

June 1

Figure 35c

Probabilities in Percent of the Five-Tenths Ice Concentration Boundary

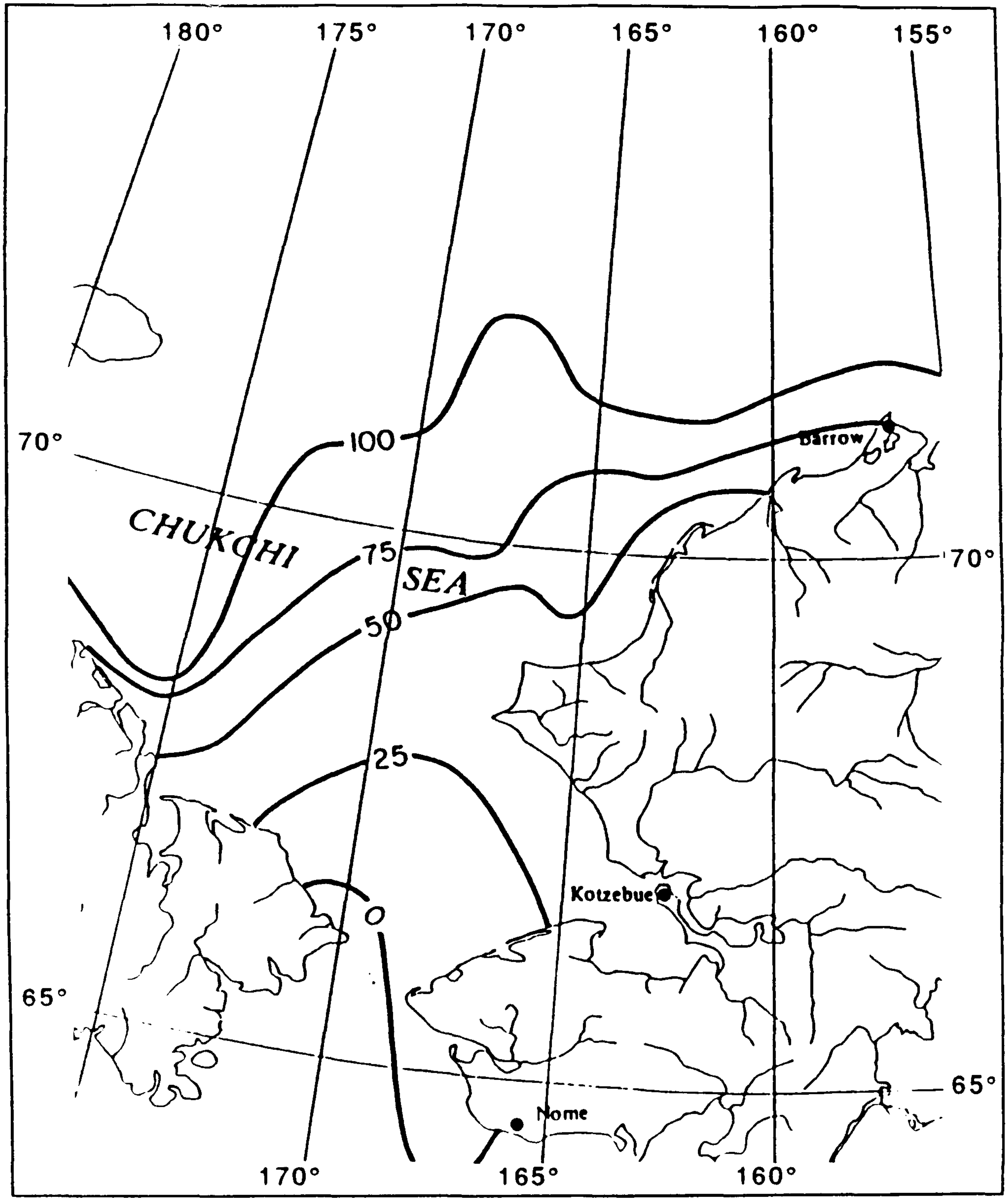


After LaBelle et al. 1983

June 15

Figure 35d

Probabilities in Percent of the Five-Tenths Ice Concentration Boundary

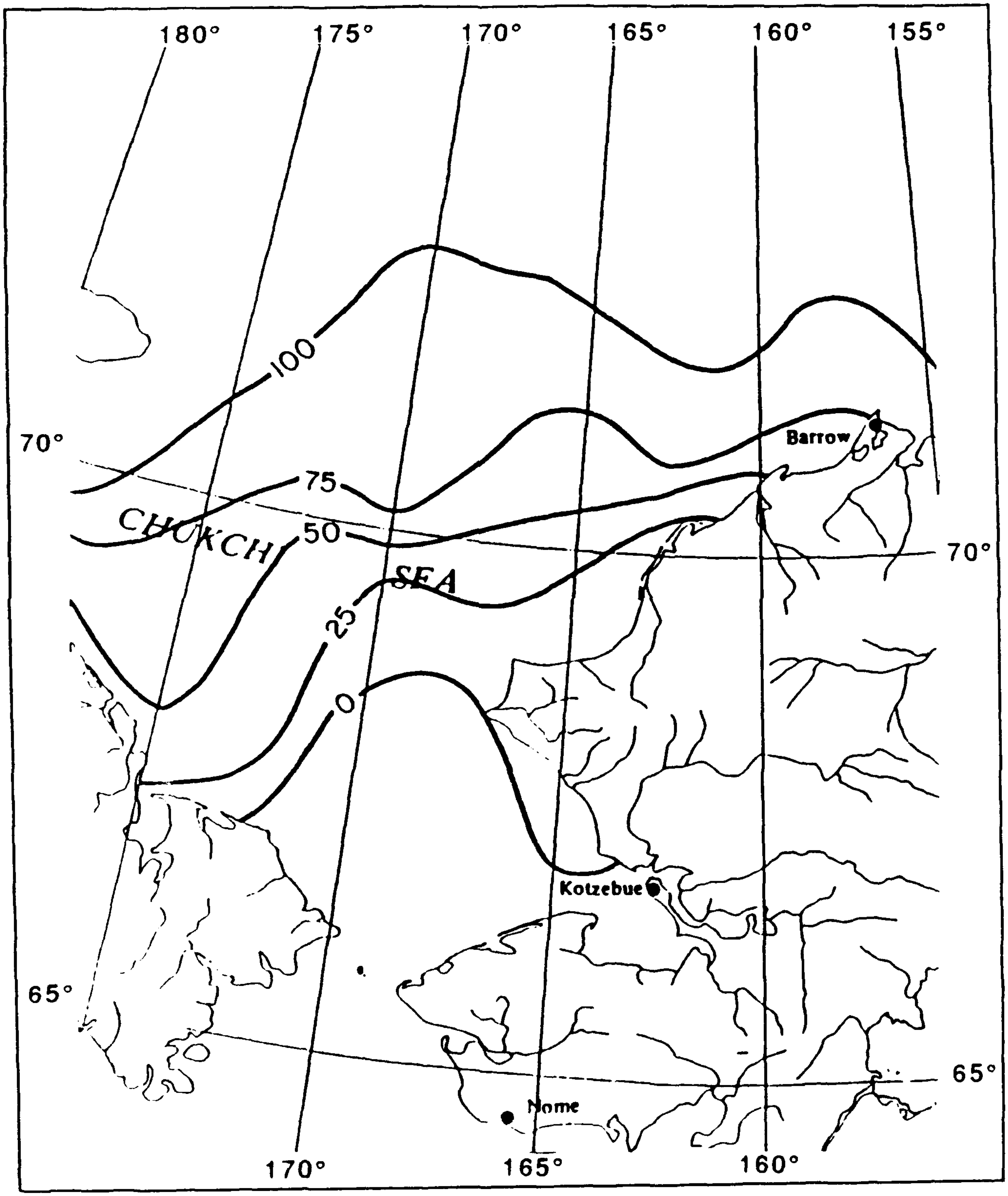


July 1

After LaBelle et al. 1983

Figure 35e

Probabilities in Percent of the Five-Tenths Ice Concentration Boundary

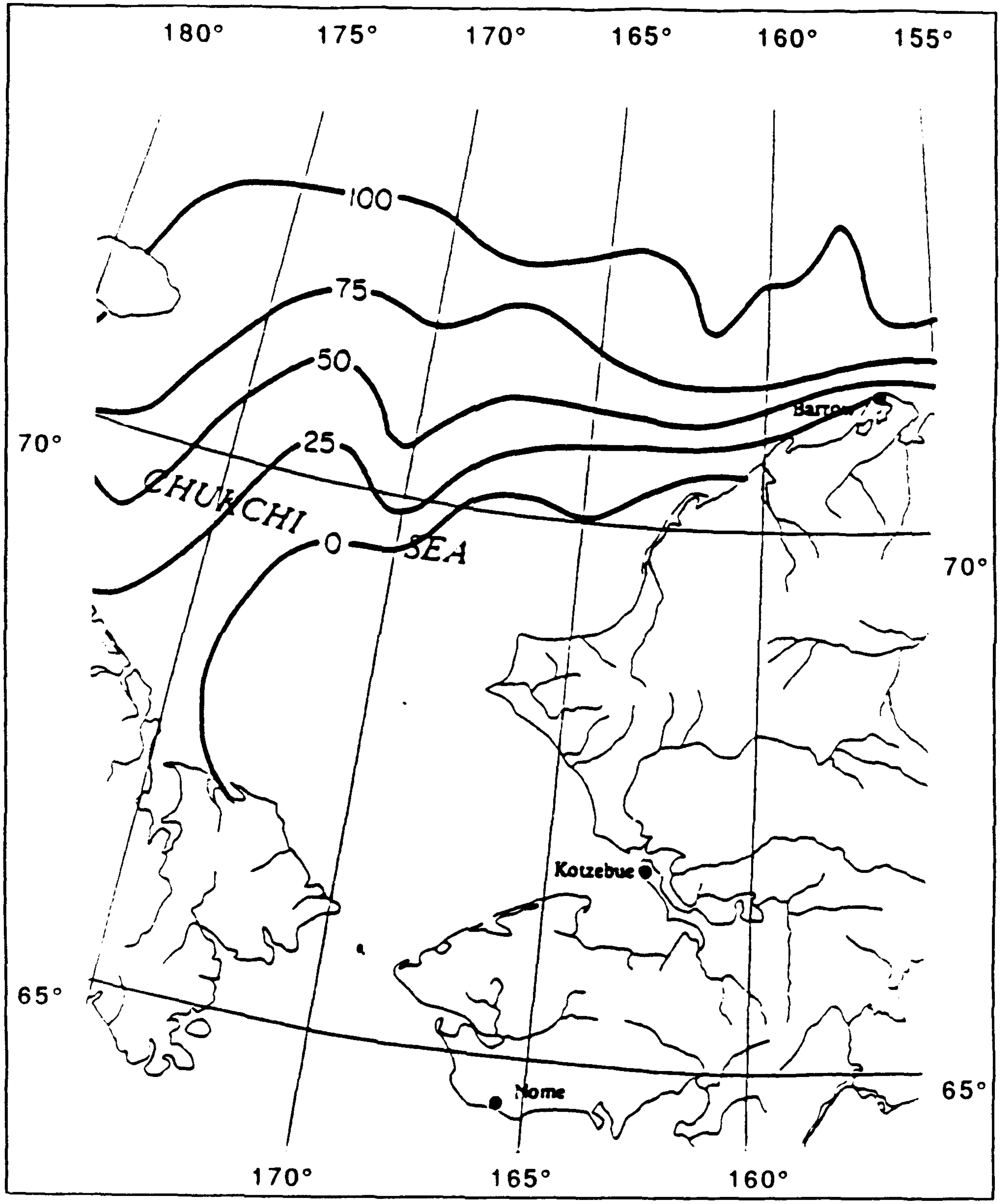


July 15

After LaBelle et al. 1983

Figure 35f

Probabilities in Percent of the Five-Tenths Ice Concentration Boundary

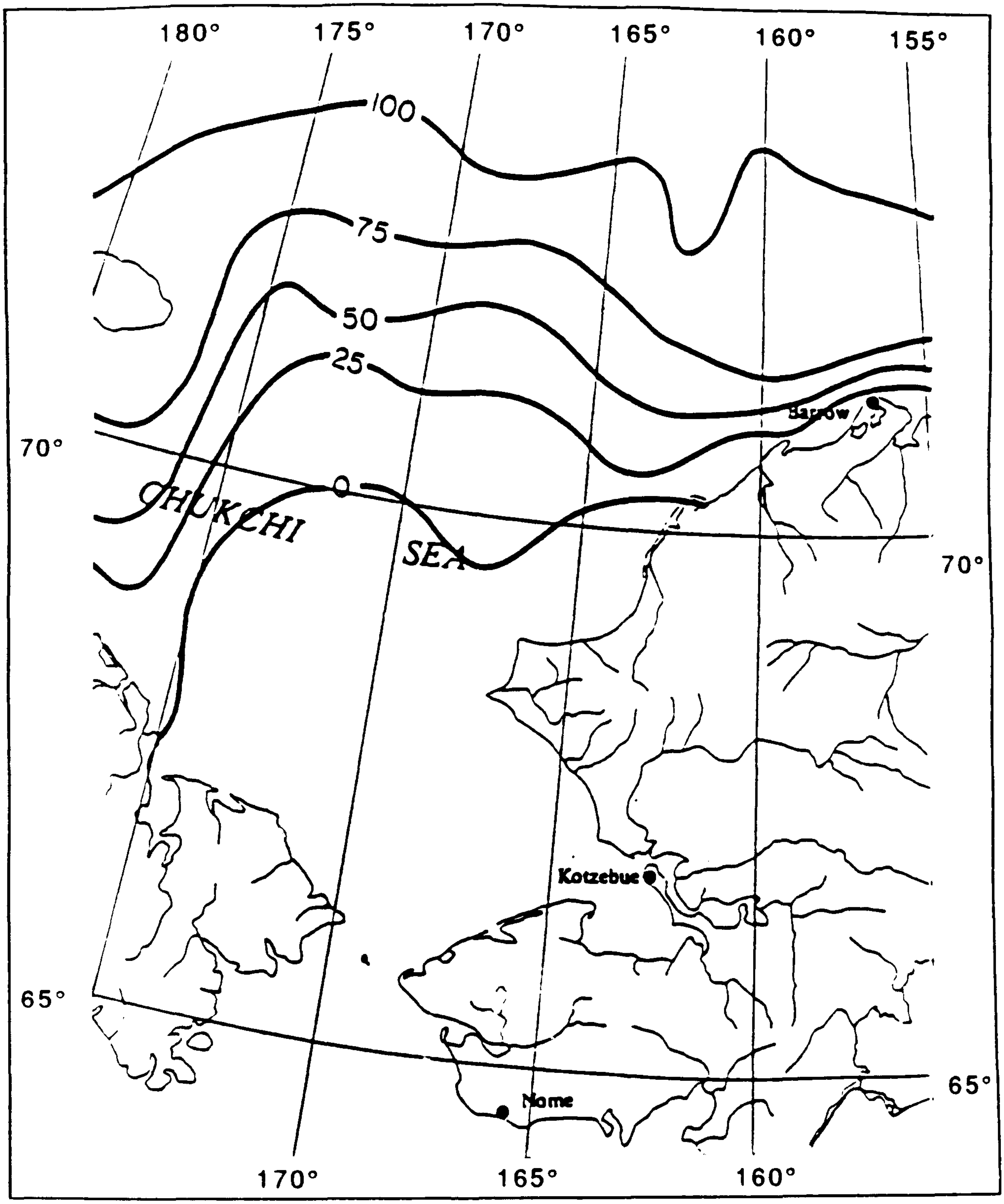


August 1

After LaBelle et al. 1983

Figure 35g

Probabilities in Percent of the Five-Tenths Ice Concentration Boundary

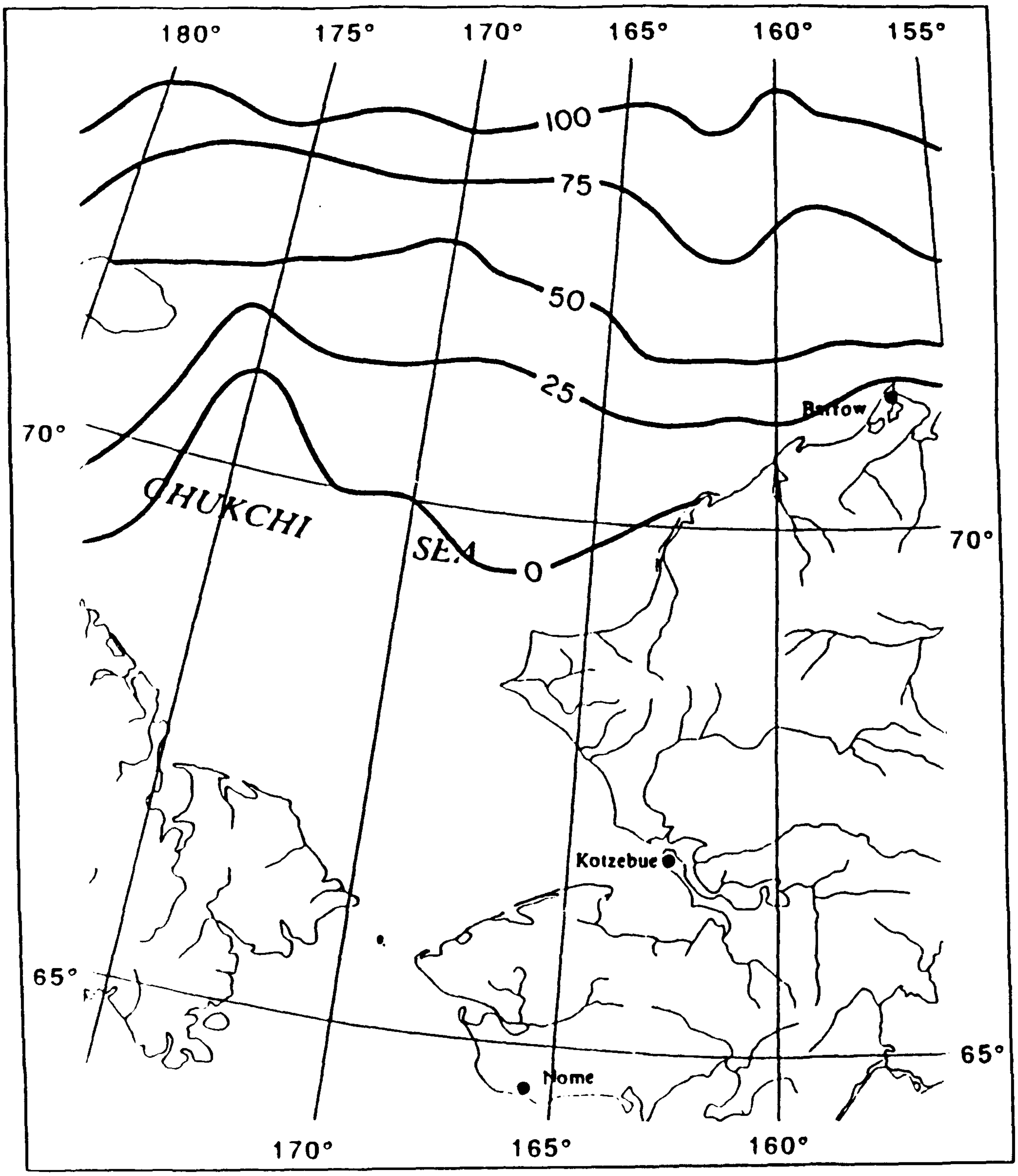


August 15

After LaBelle et al. 1983

Figure 35h

Probabilities in Percent of the Five-Tenths Ice Concentration Boundary

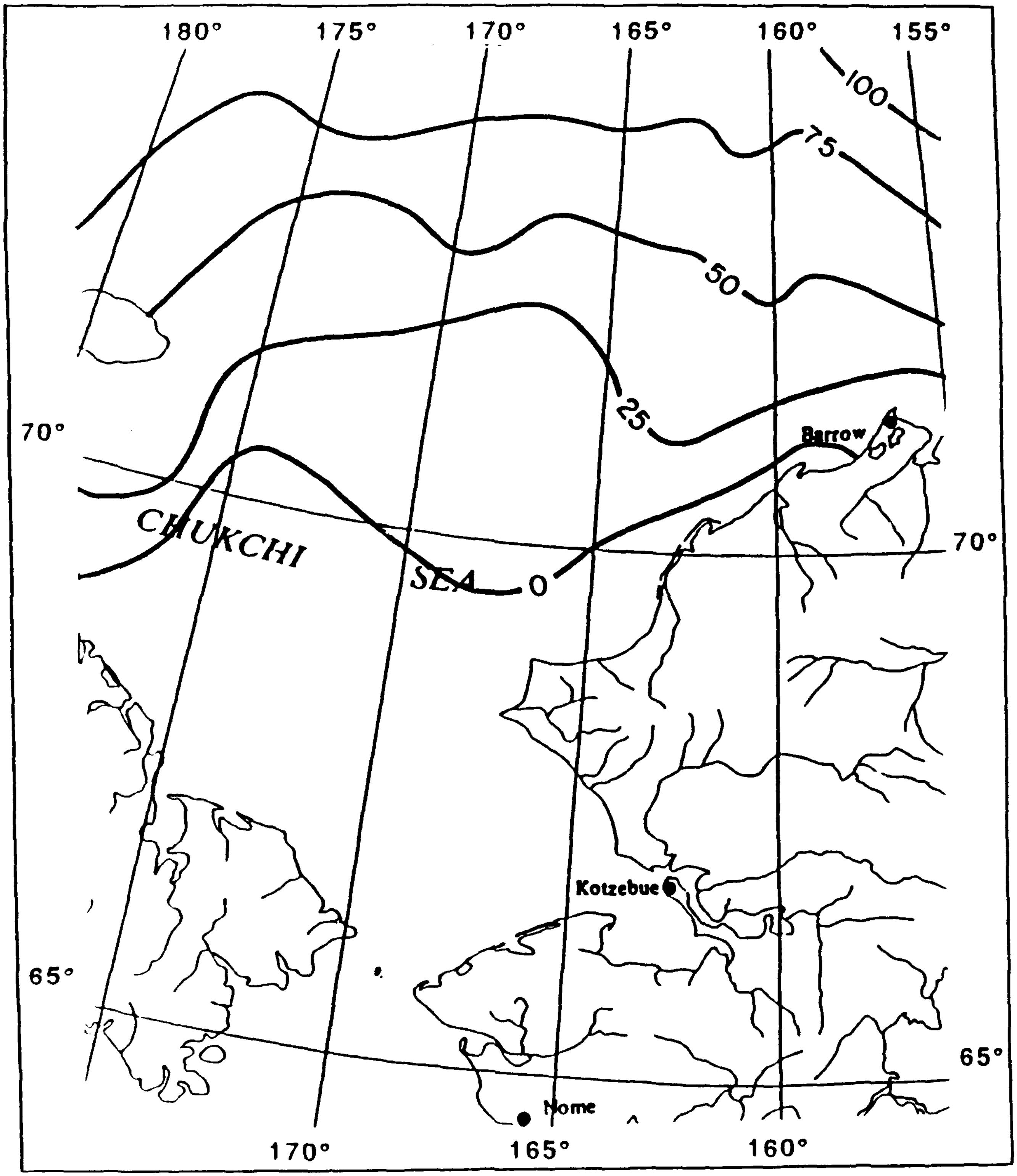


September 1

After LaBelle et al. 1983

Figure 35i

Probabilities in Percent of the Five-Tenths Ice Concentration Boundary

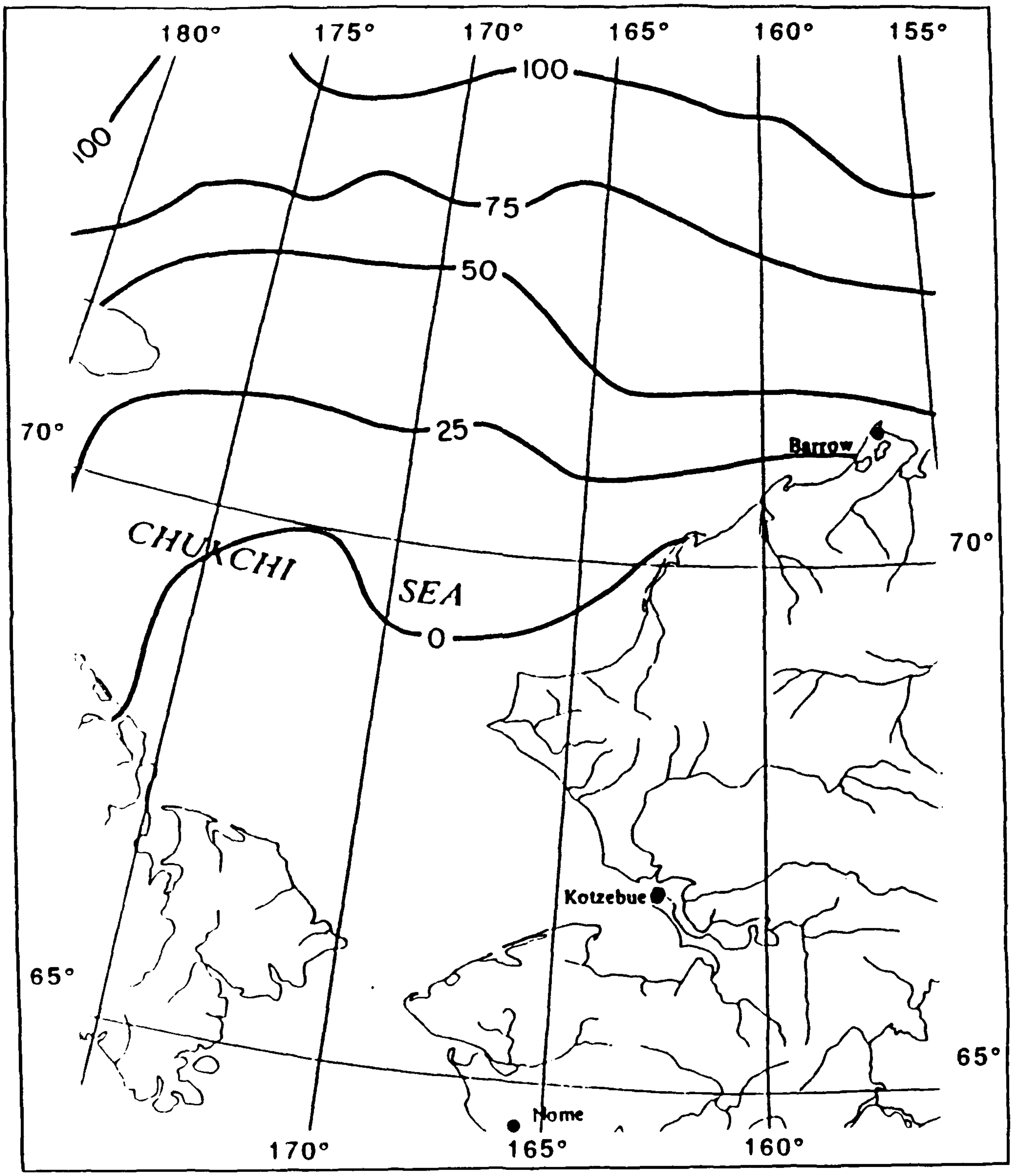


September 15

After LaBelle et al. 1983

Figure 35j

Probabilities in Percent of the Five-Tenths Ice Concentration Boundary

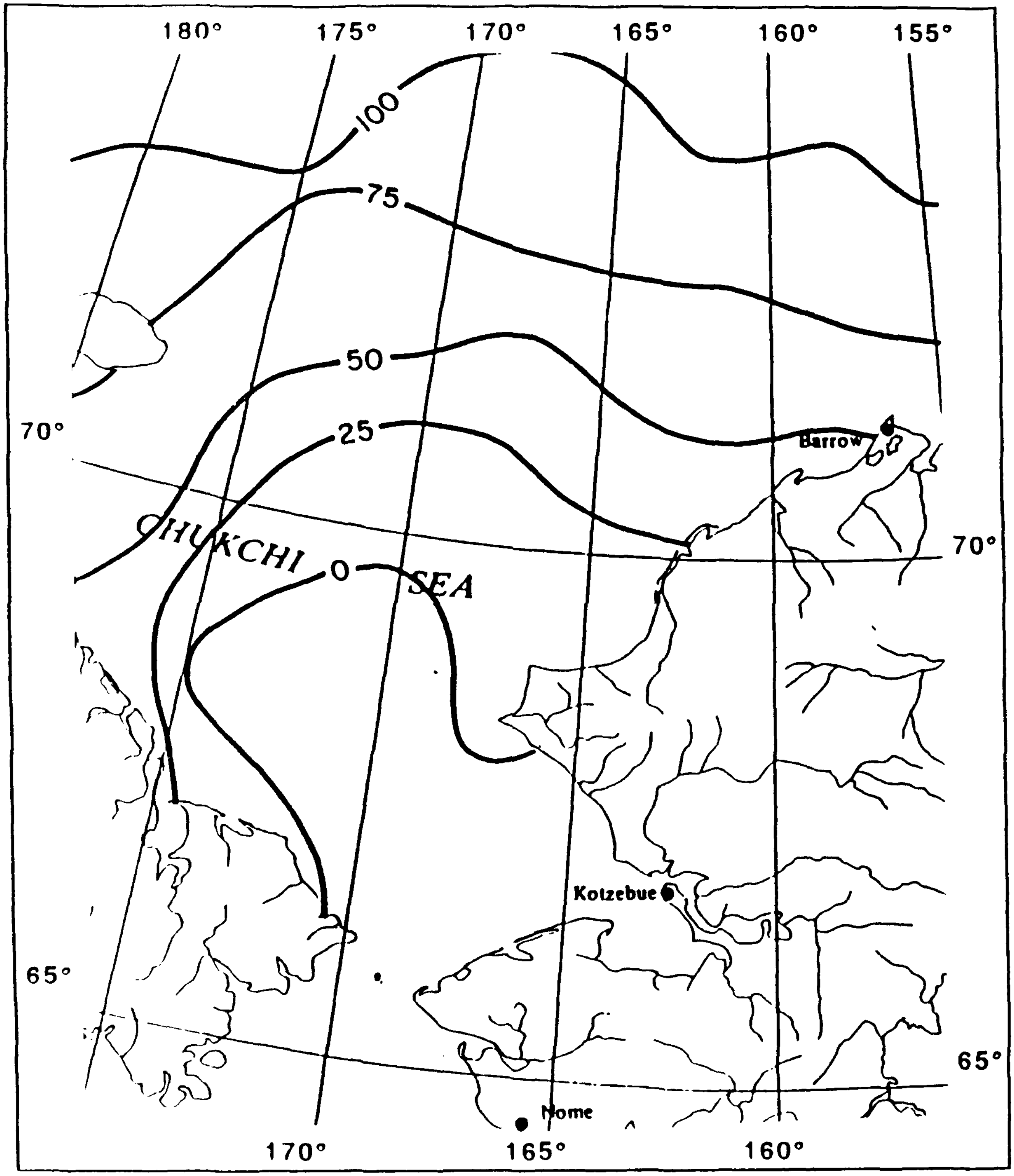


October 1

After LaBelle et al. 1983

Figure 35k

Probabilities in Percent of the Five-Tenths Ice Concentration Boundary

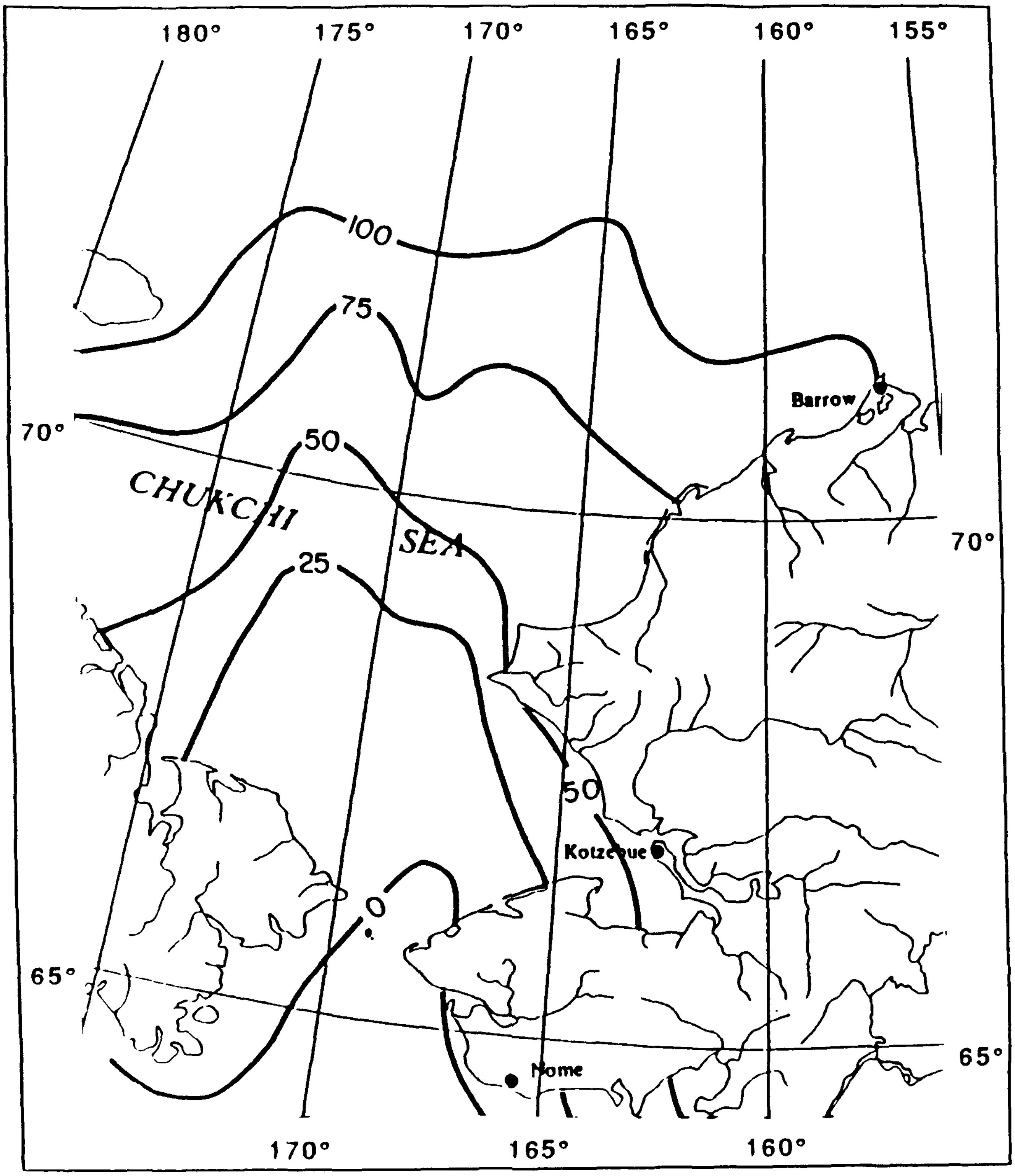


October 15

After LaBelle et al. 1983

Figure 35I

Probabilities in Percent of the Five-Tenths Ice Concentration Boundary

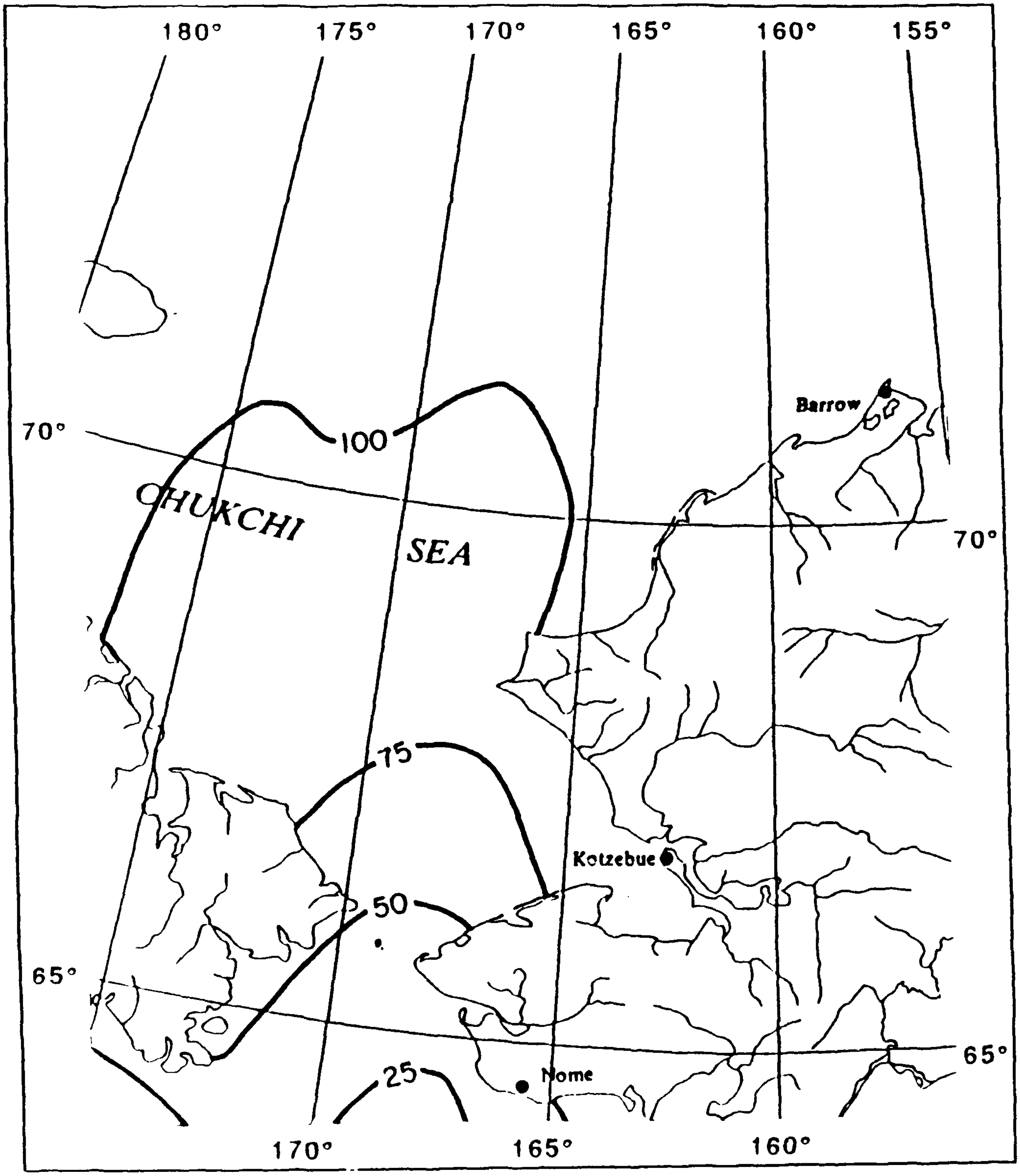


November 1

After LaBelle et al. 1983

Figure 35m

Probabilities in Percent of the Five-Tenths Ice Concentration Boundary

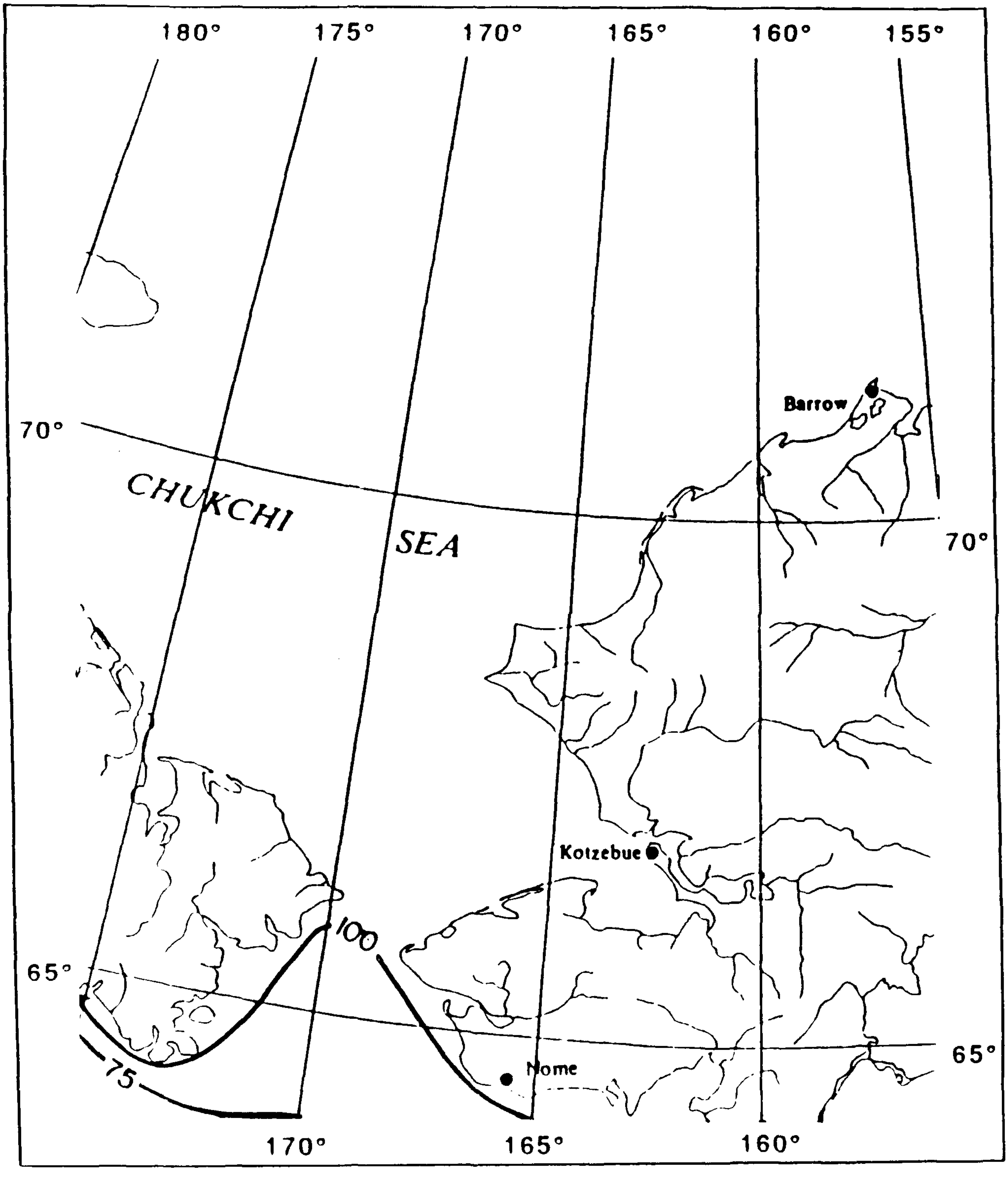


After LaBelle et al. 1983

November 15

Figure 35n

Probabilities in Percent of the Five-Tenths Ice Concentration Boundary

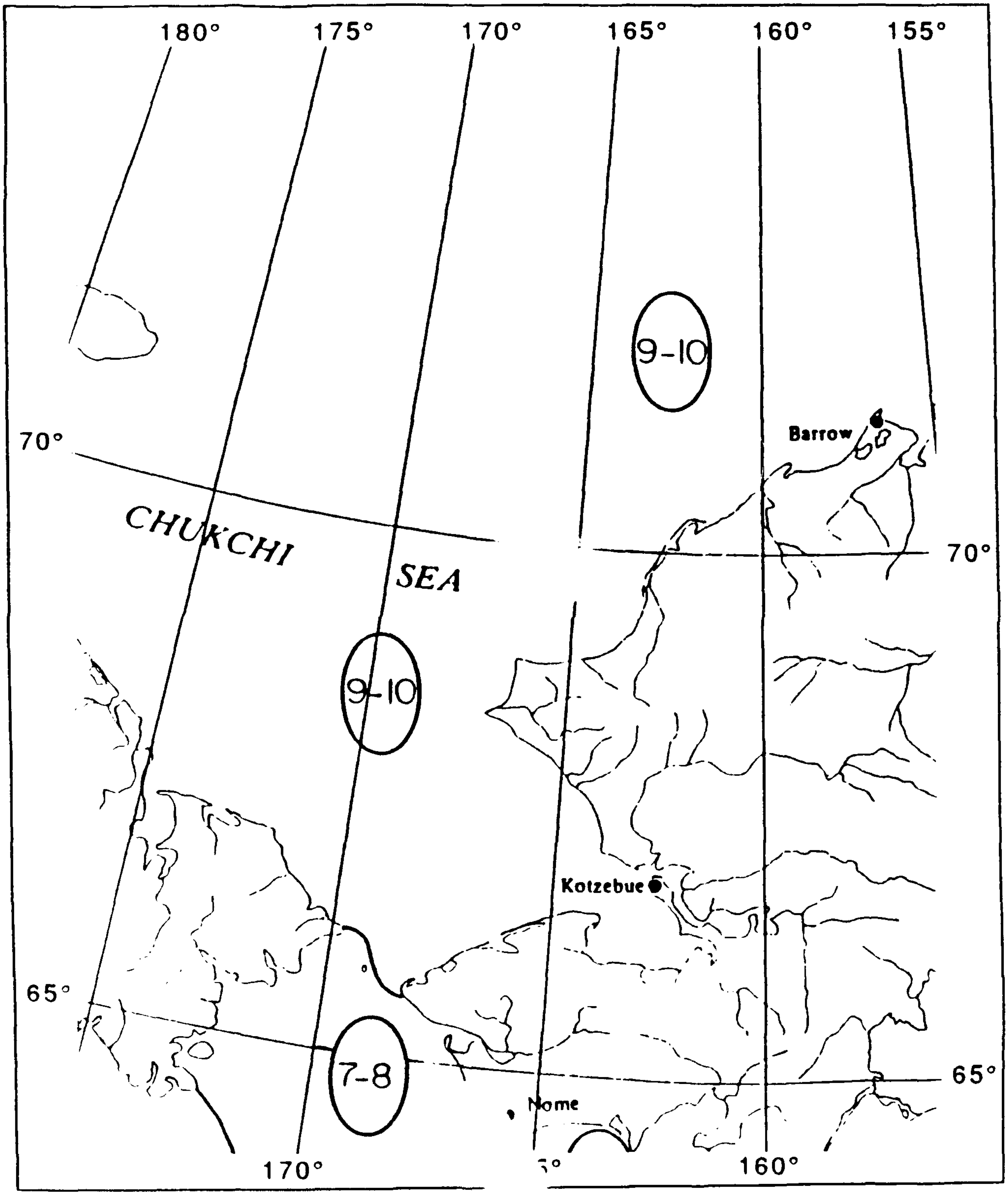


December 1

After LaBelle et al. 1983

Figure 35o

Ice Concentration

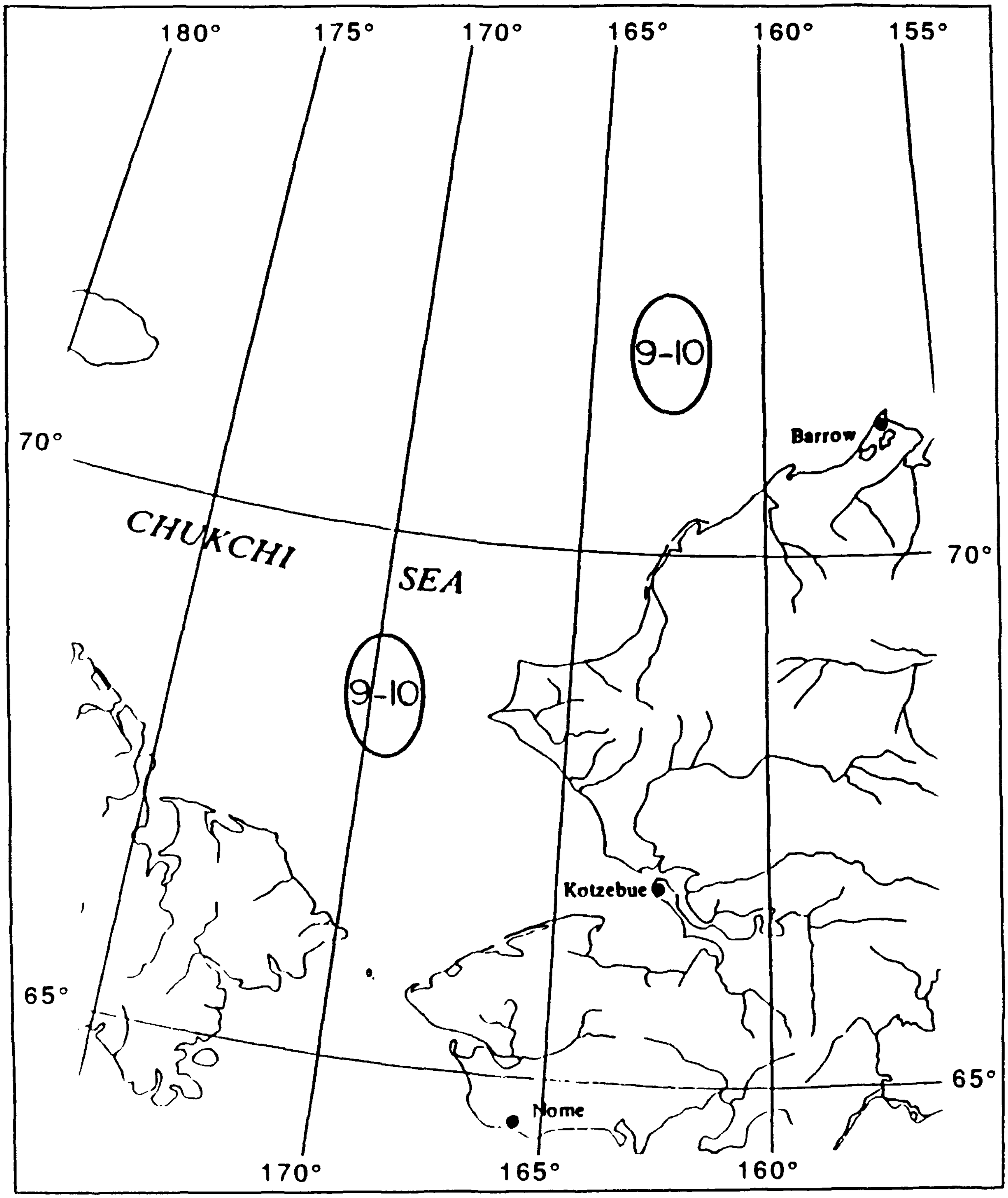


Jan y

After LaBelle et al. 1983

Figure 36a

Ice Concentration

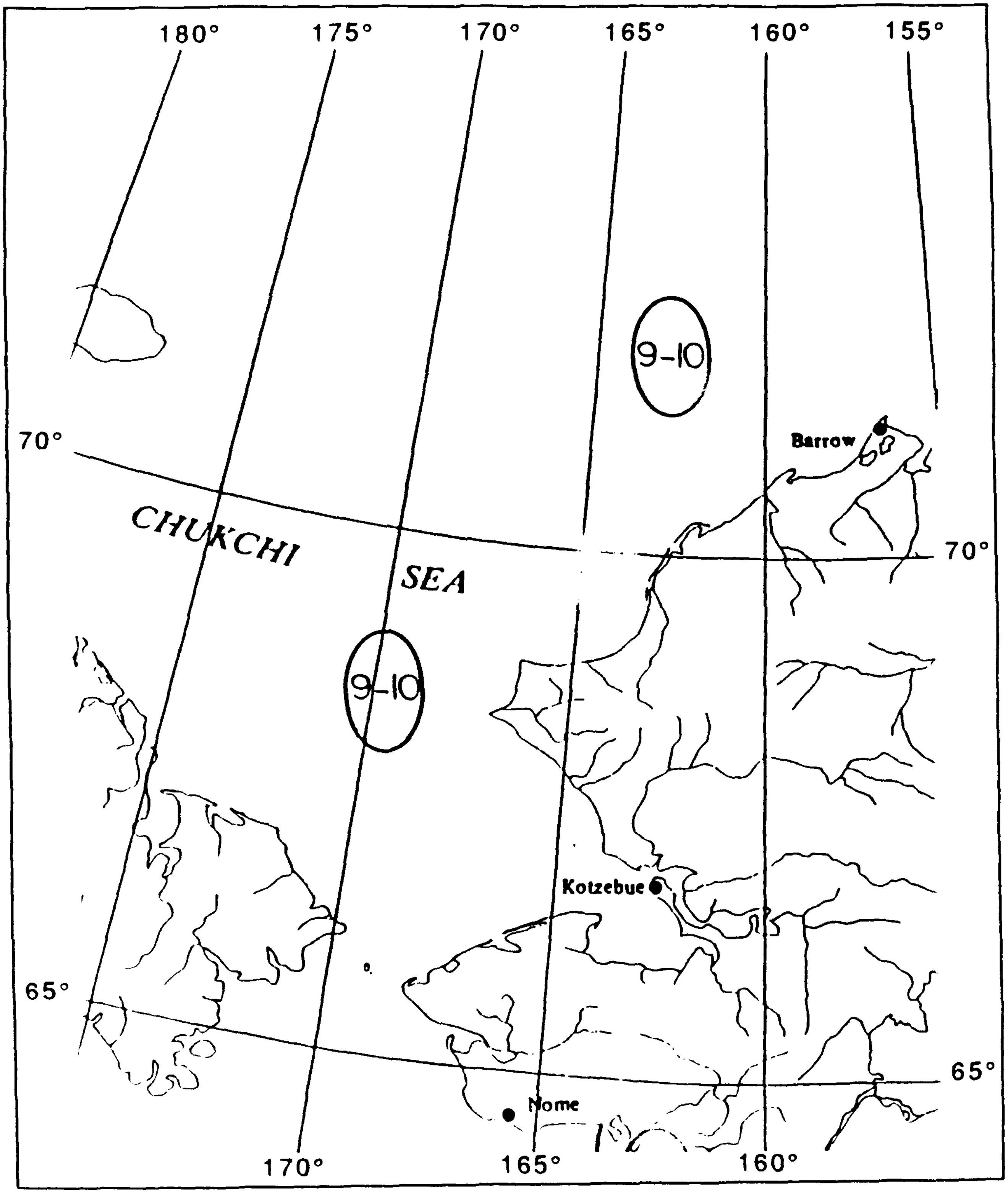


February

After LaBelle et al. 1983

Figure 36b

Ice Concentration

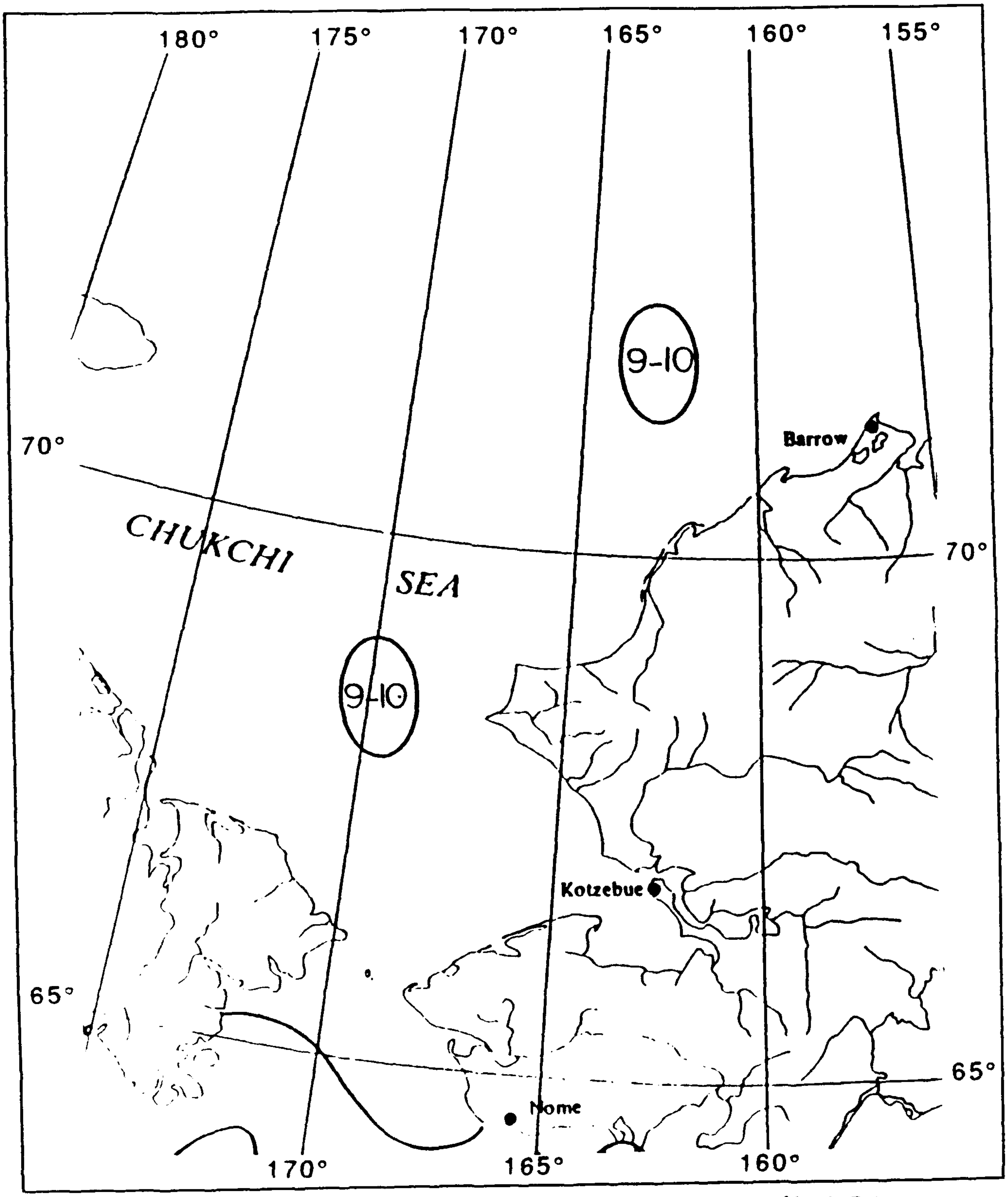


After LaBelle et al. 1983

March

Figure 36c

Ice Concentration

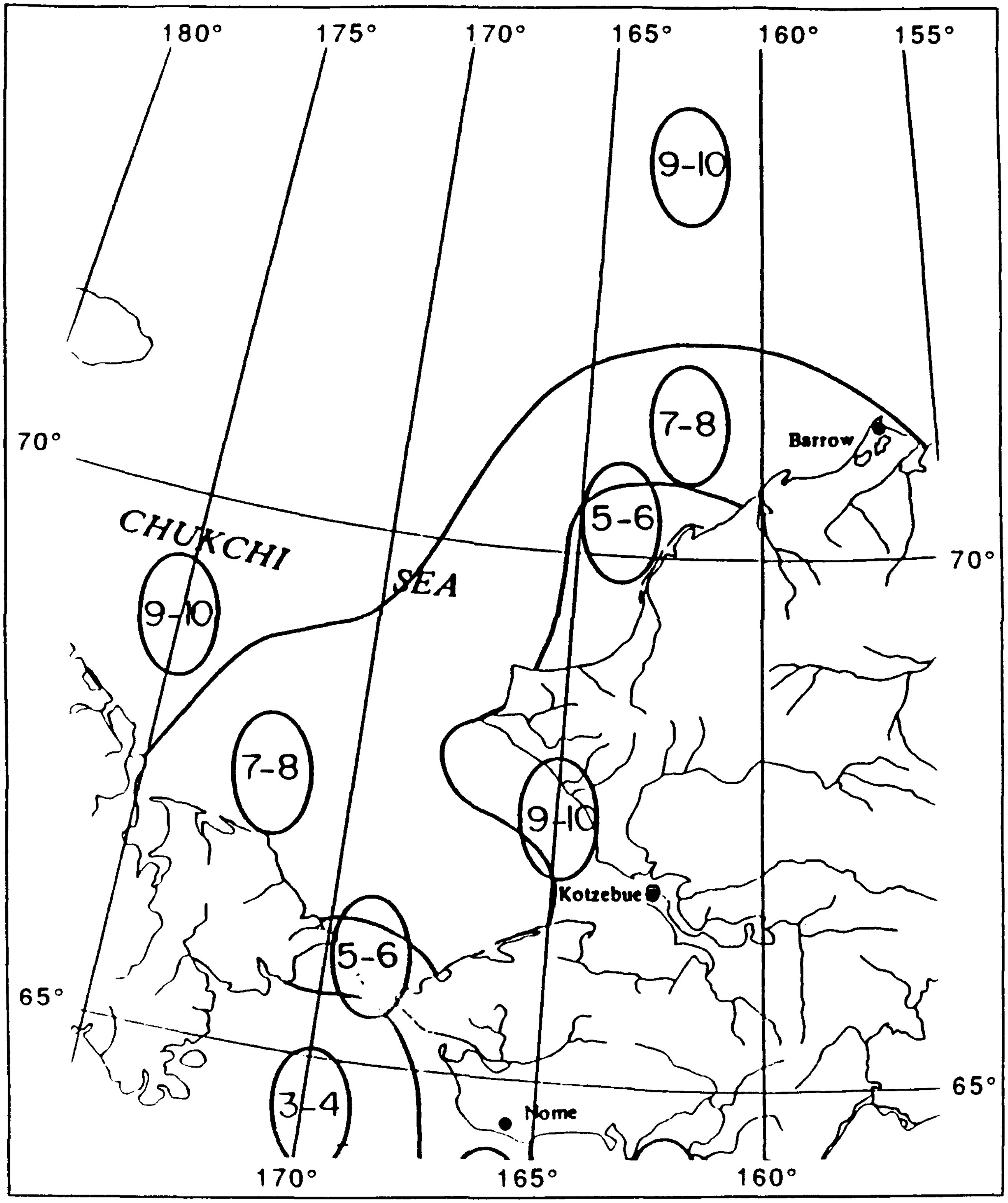


After LaBelle et al. 1983

April

Figure 36d

Ice Concentration

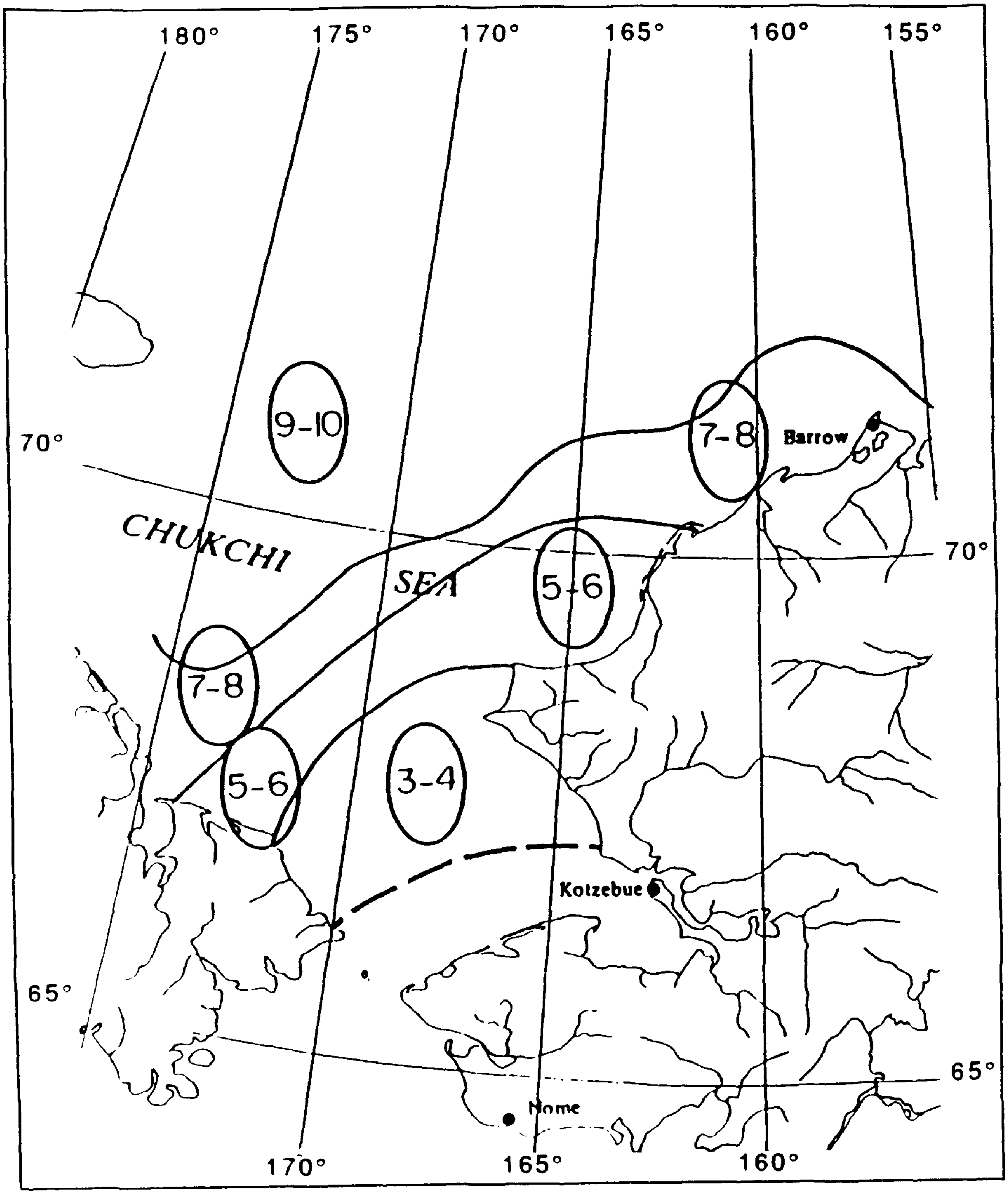


May

After LaBelle et al. 1983

Figure 36e

Ice Concentration

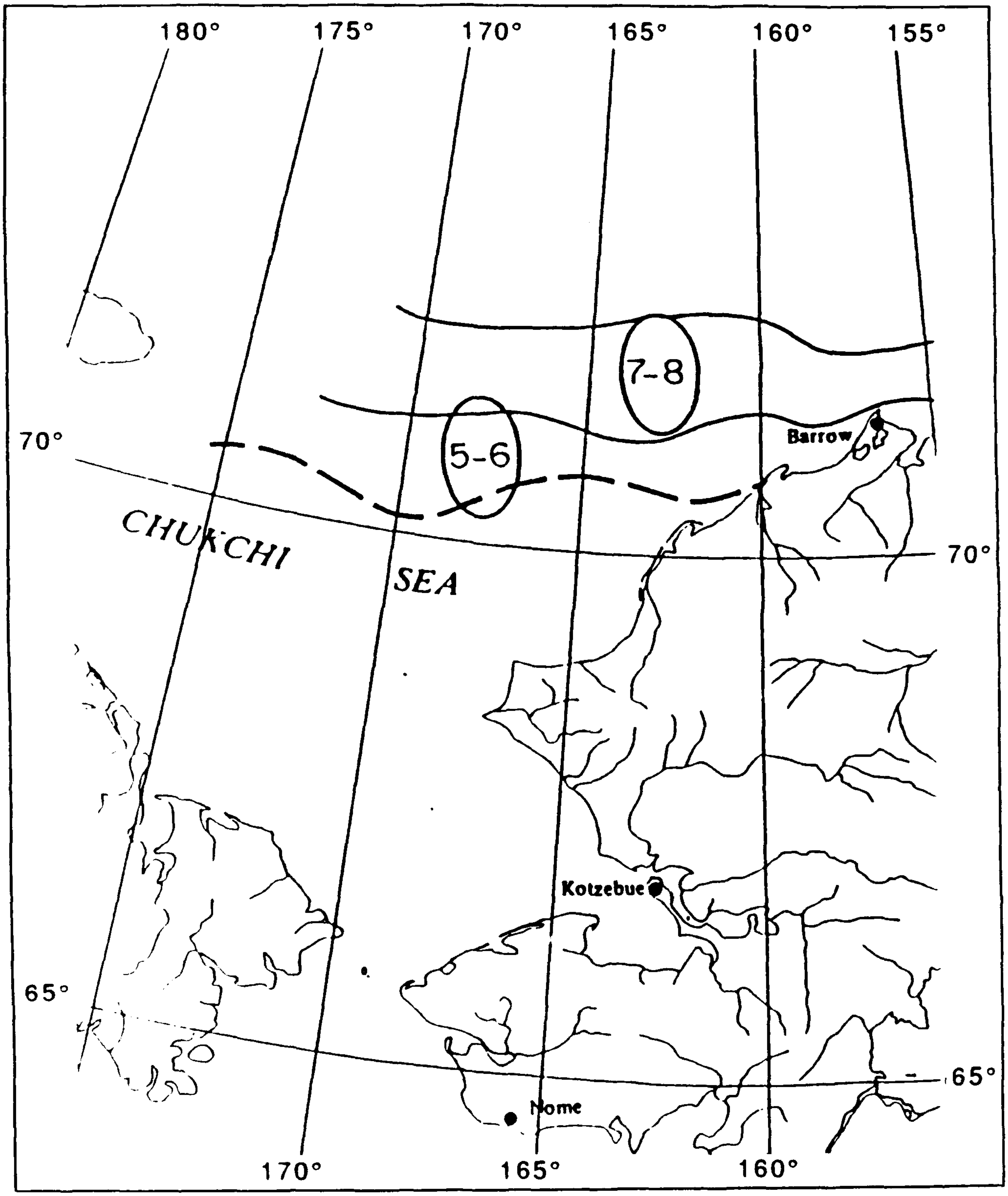


After LaBelle et al. 1983

June

Figure 36f

Ice Concentration

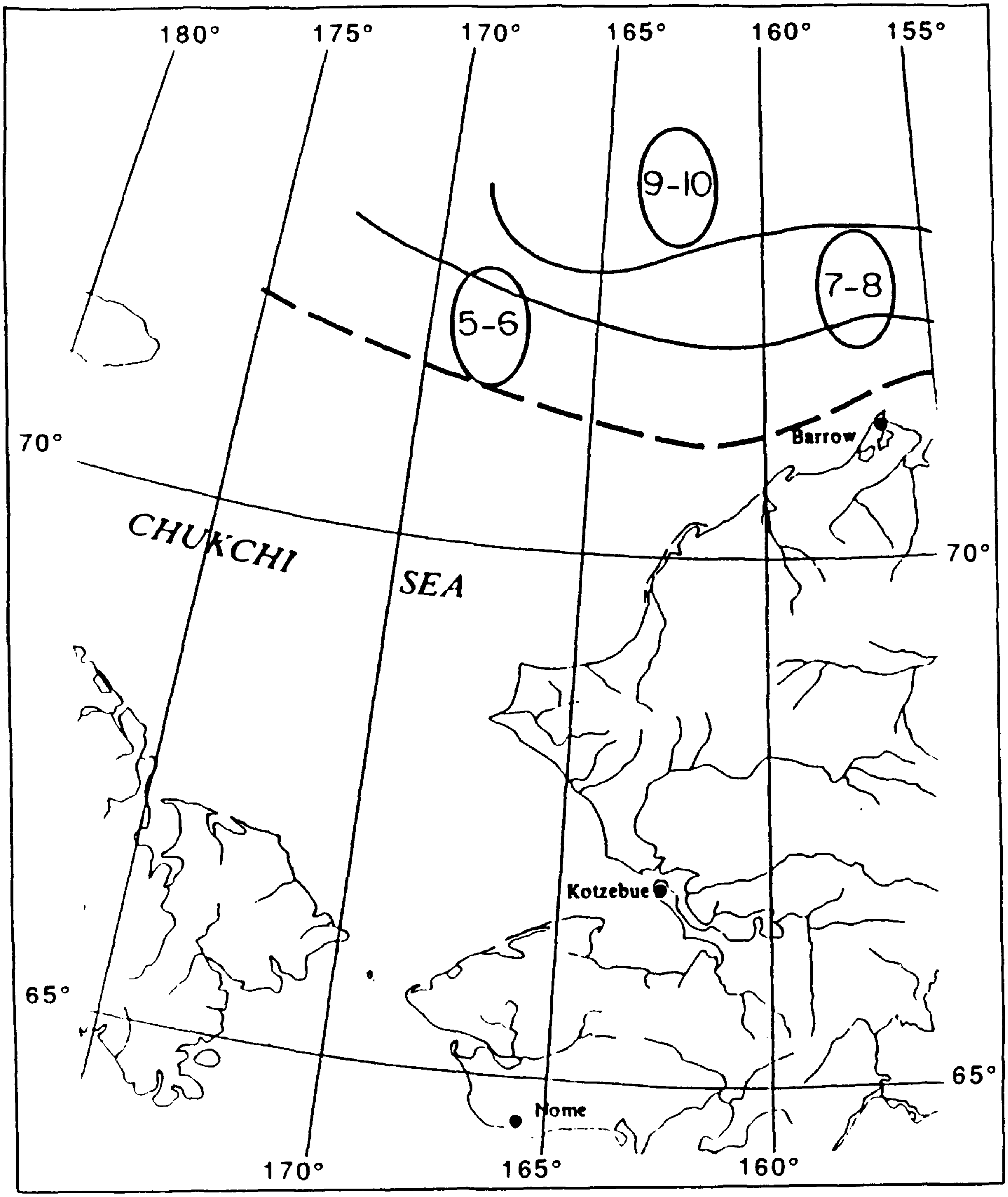


July

After LaBelle et al. 1983

Figure 36g

Ice Concentration

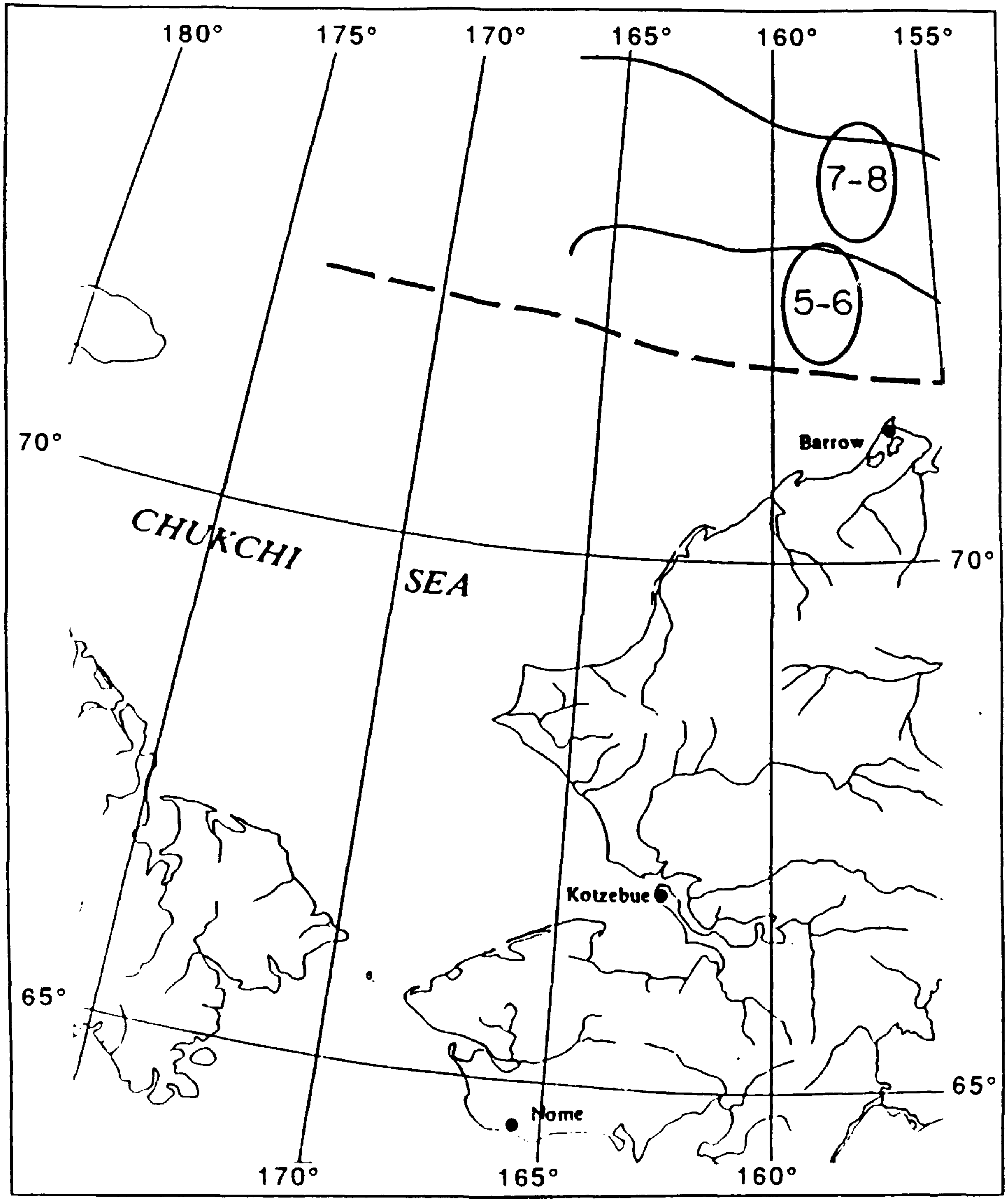


After LaBelle et al. 1983

August

Figure 36h

Ice Concentration

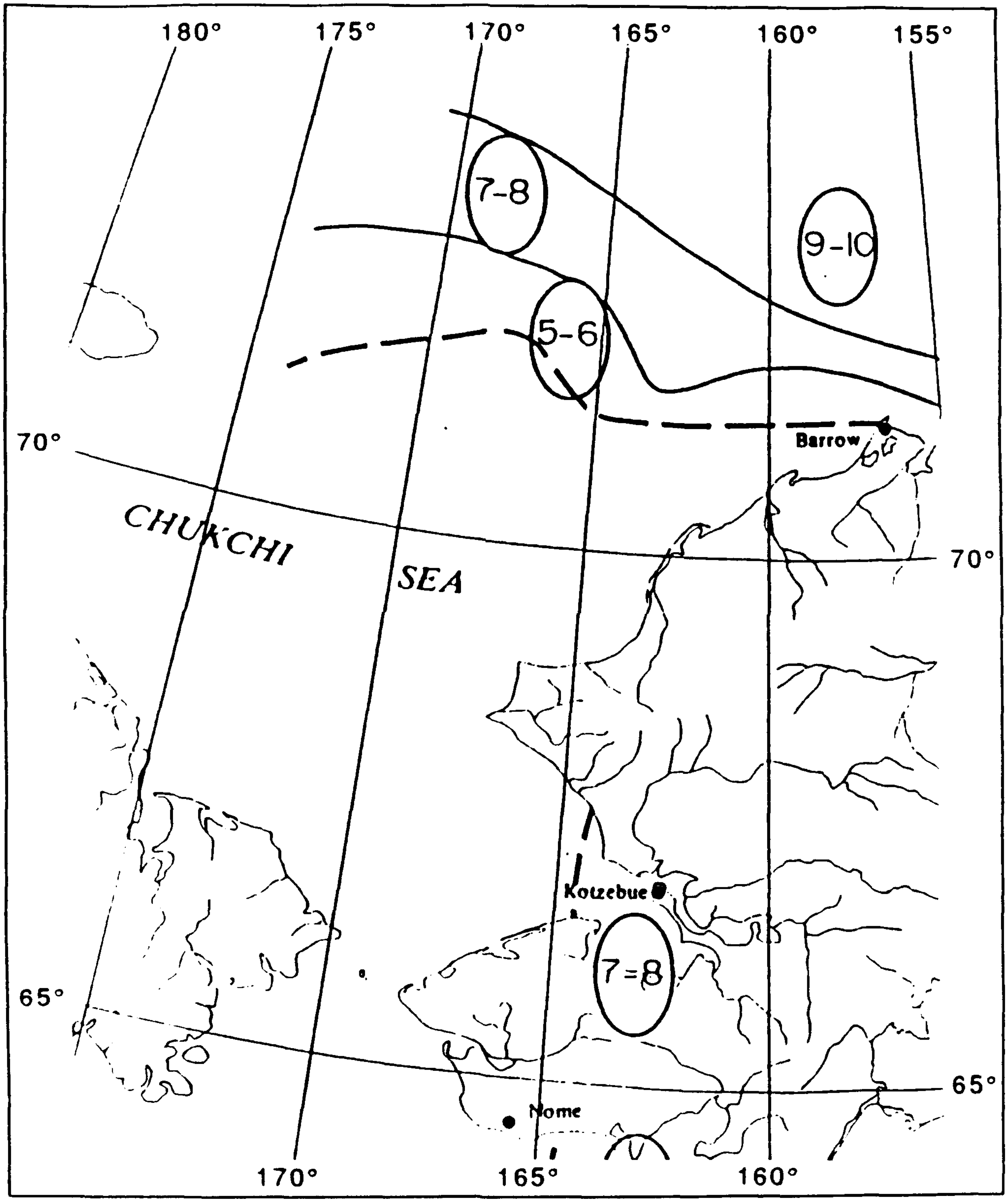


September

After LaBelle et al. 1983

Figure 36i

Ice Concentration

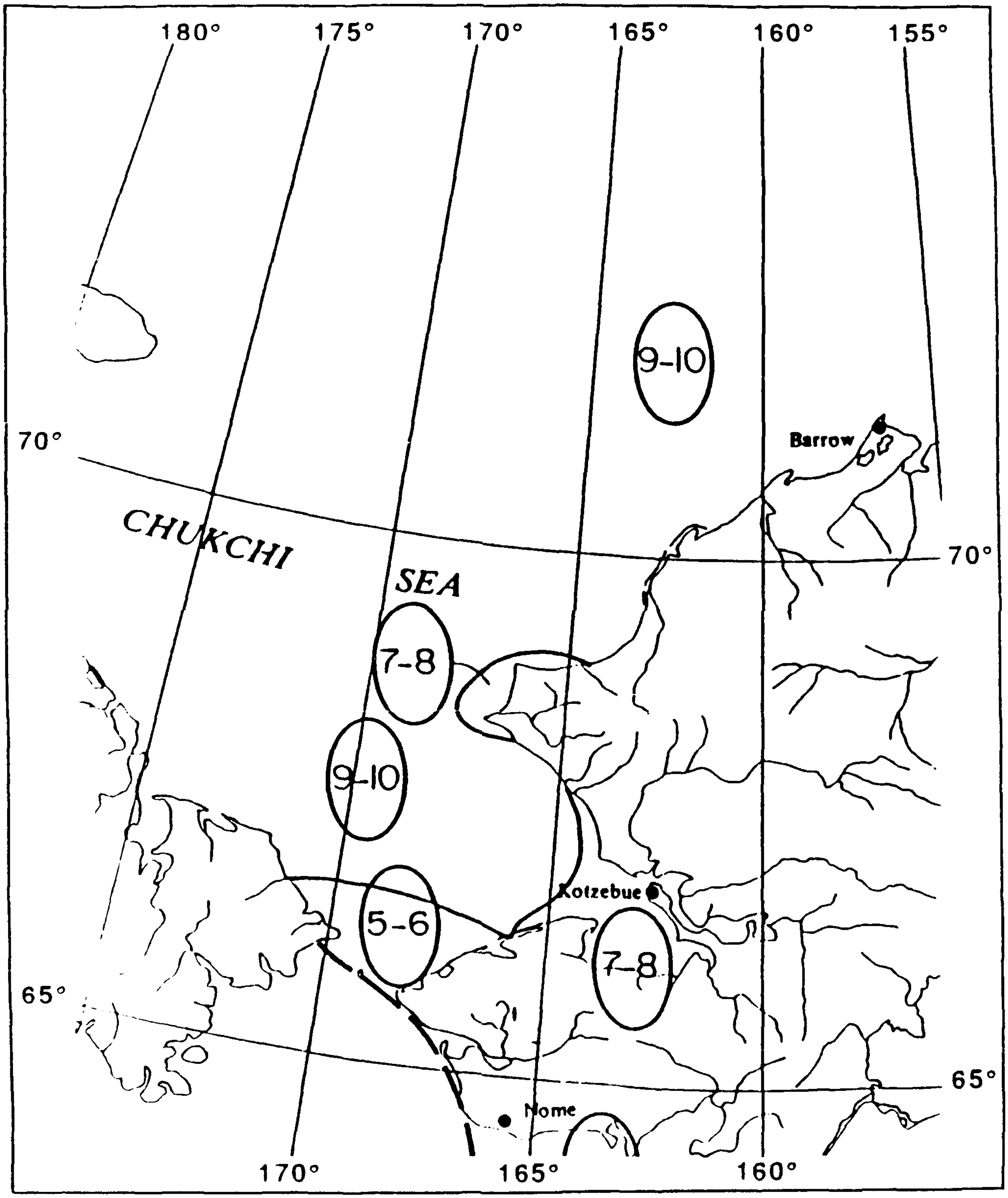


October

After LaBelle et al. 1983

Figure 36j

Ice Concentration

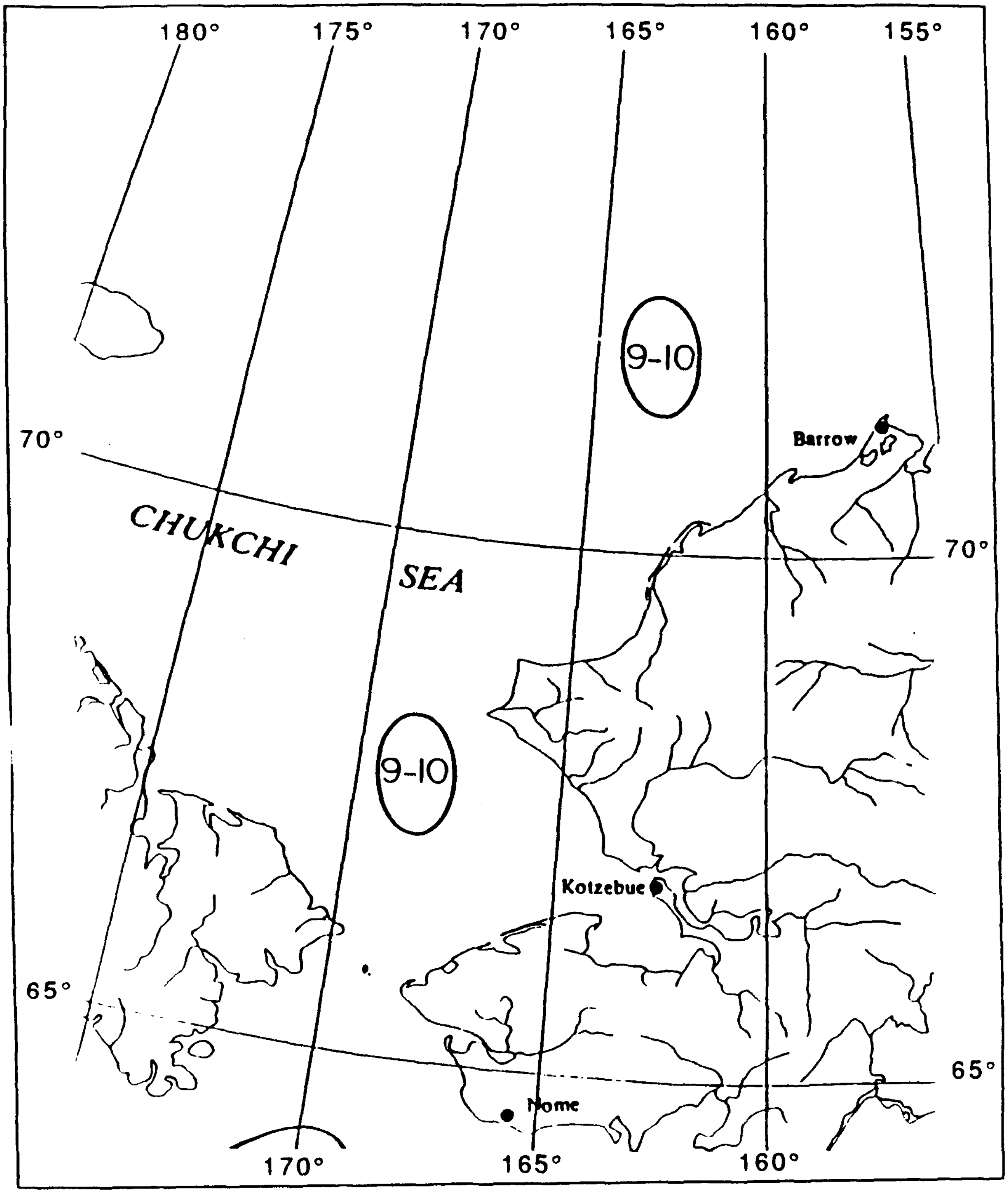


After LaBelle et al. 1983

November

Figure 36k

Ice Concentration

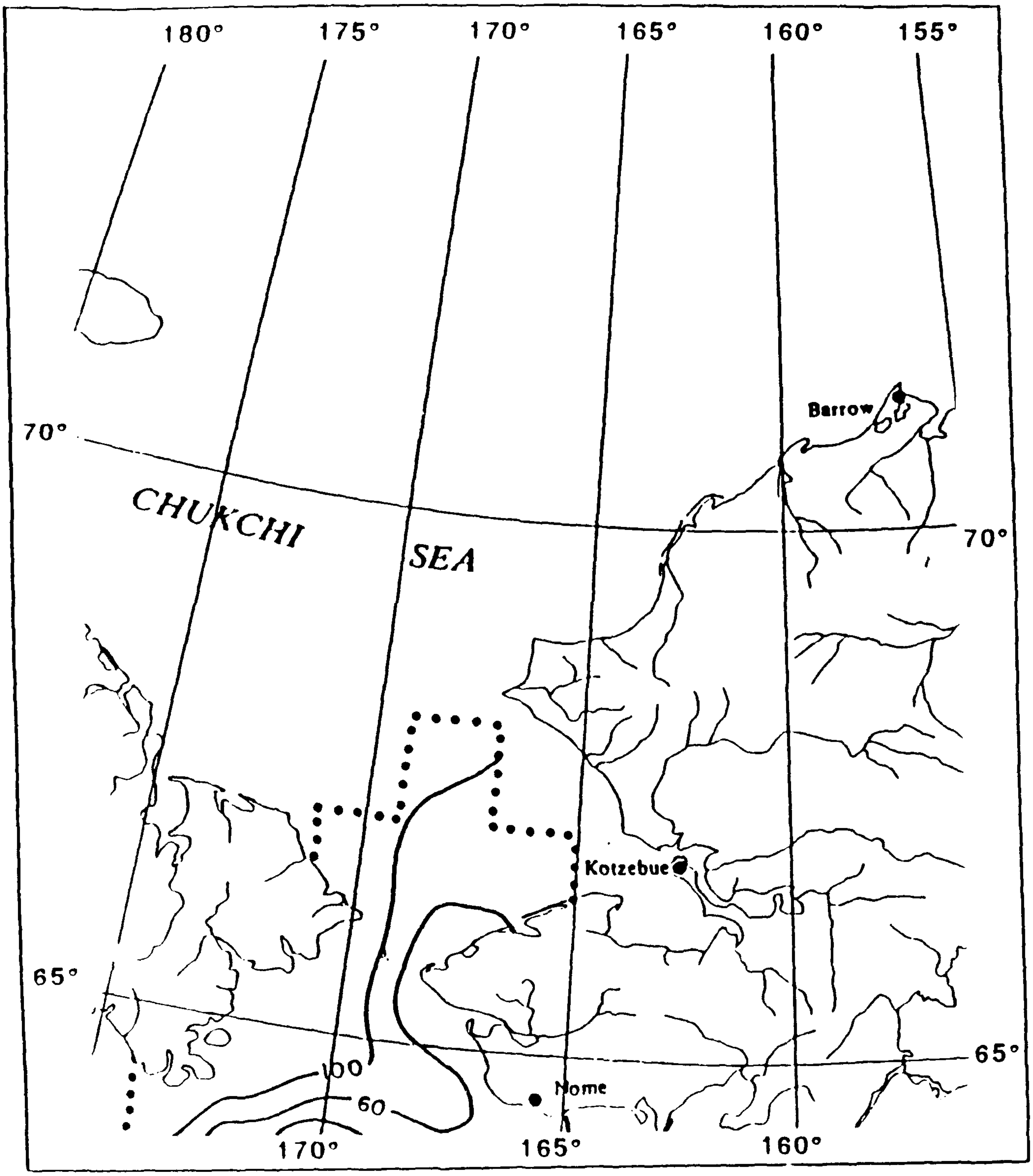


December

After LaBelle et al. 1983

Figure 36l

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

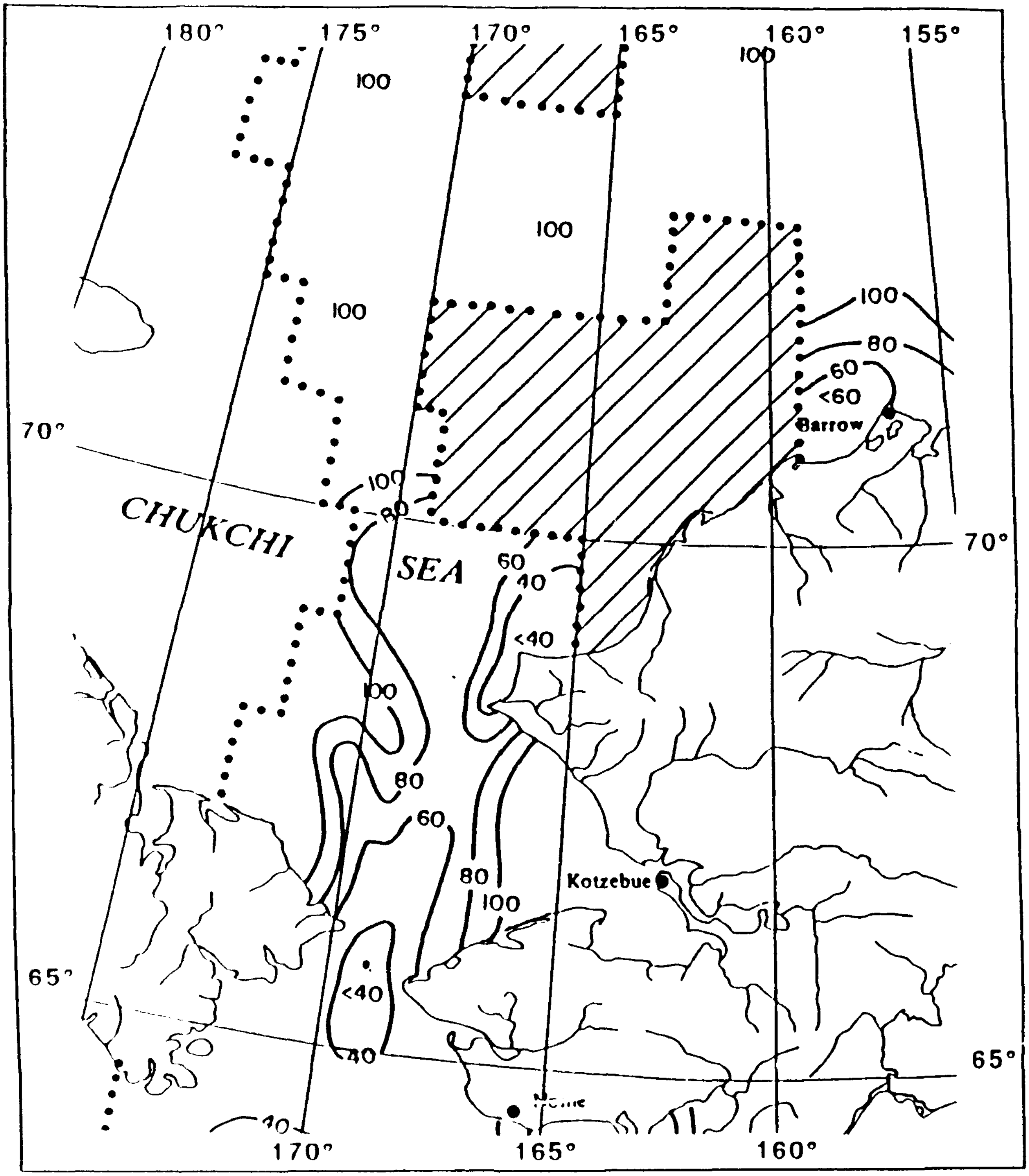


January 1-15

After LaBelle et al. 1983

Figure 37a

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

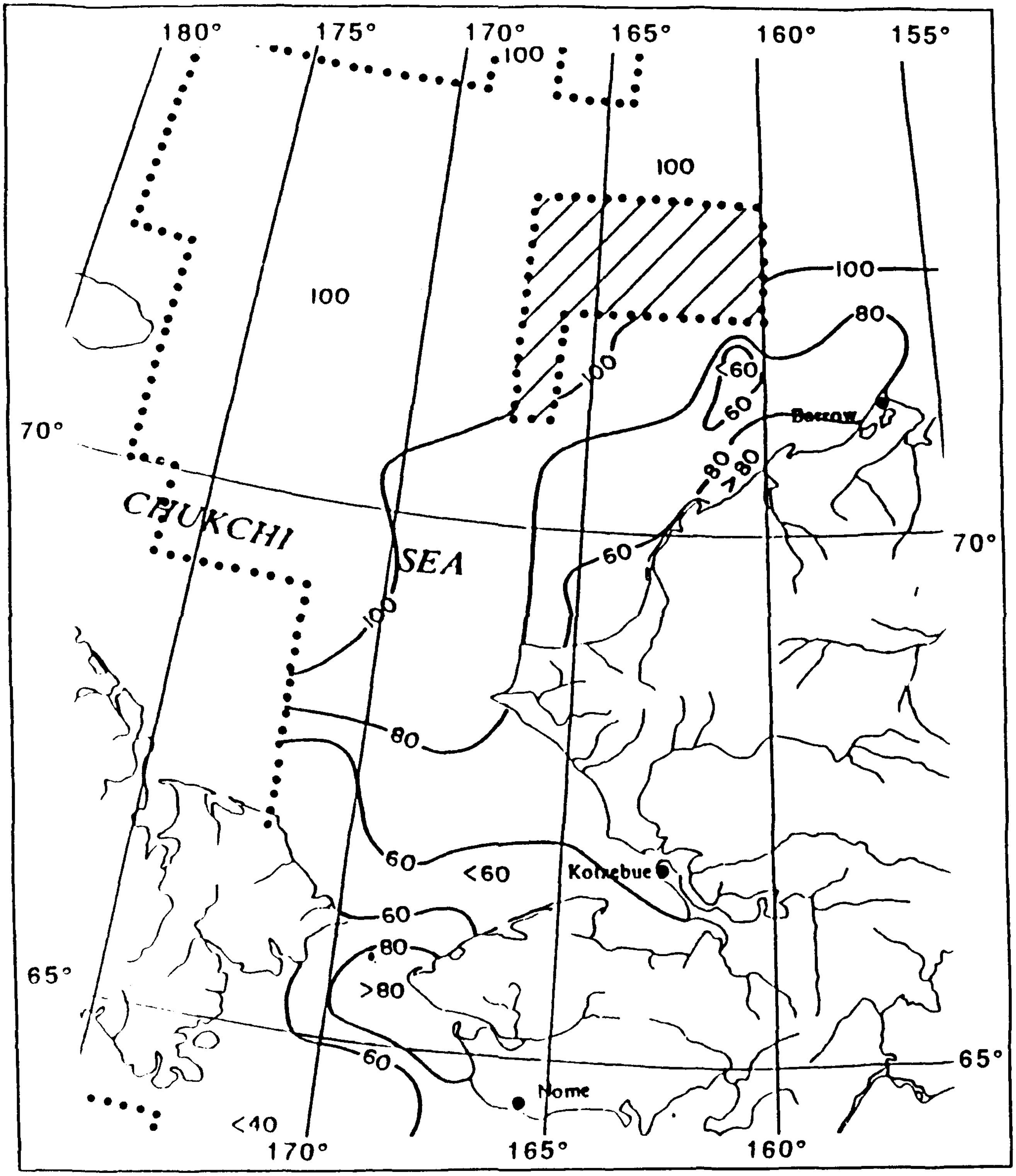


January 16-31

After LaBelle et al. 1983

Figure 37b

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

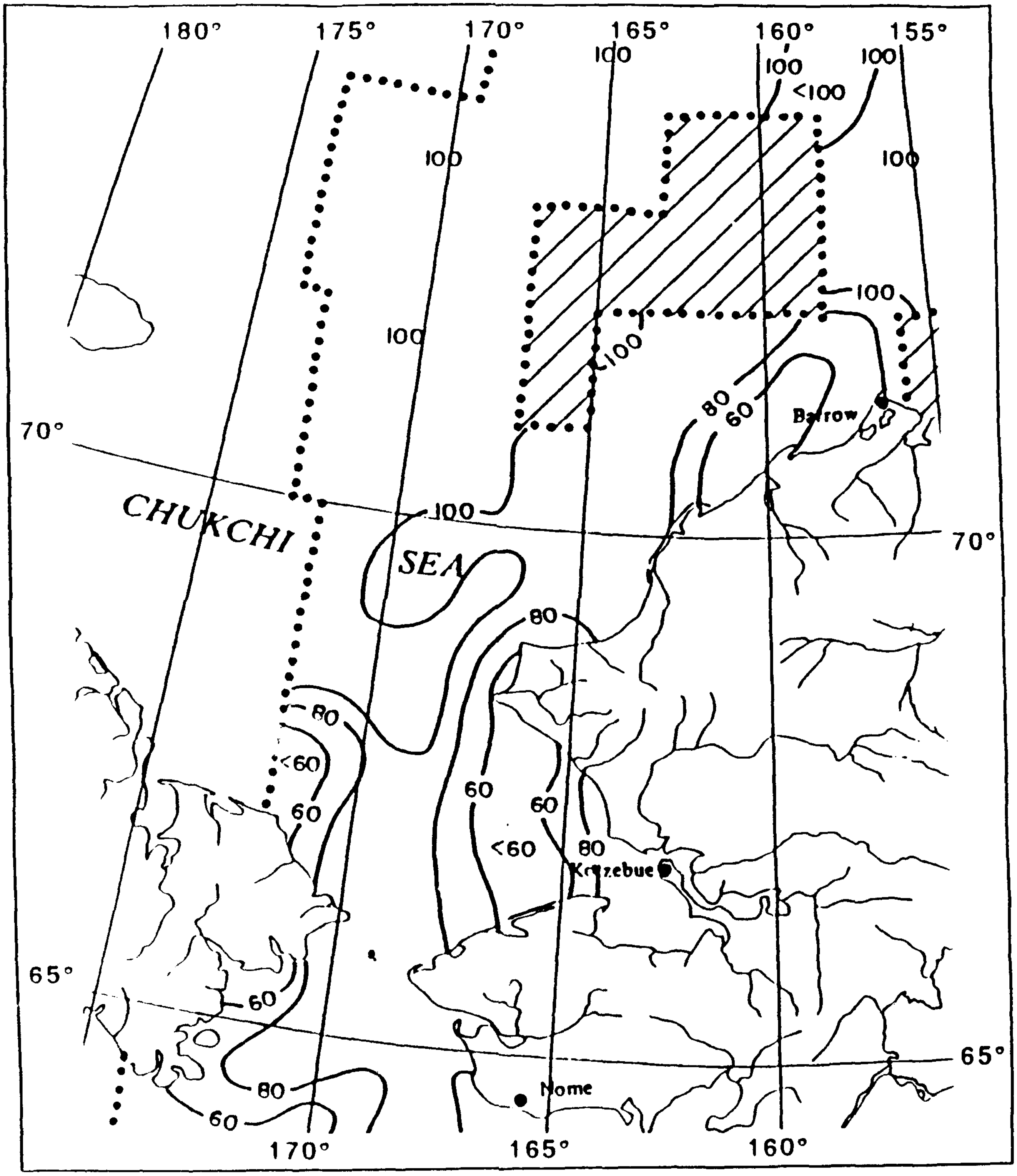


February 1-15

After LaBelle et al. 1983

Figure 37c

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

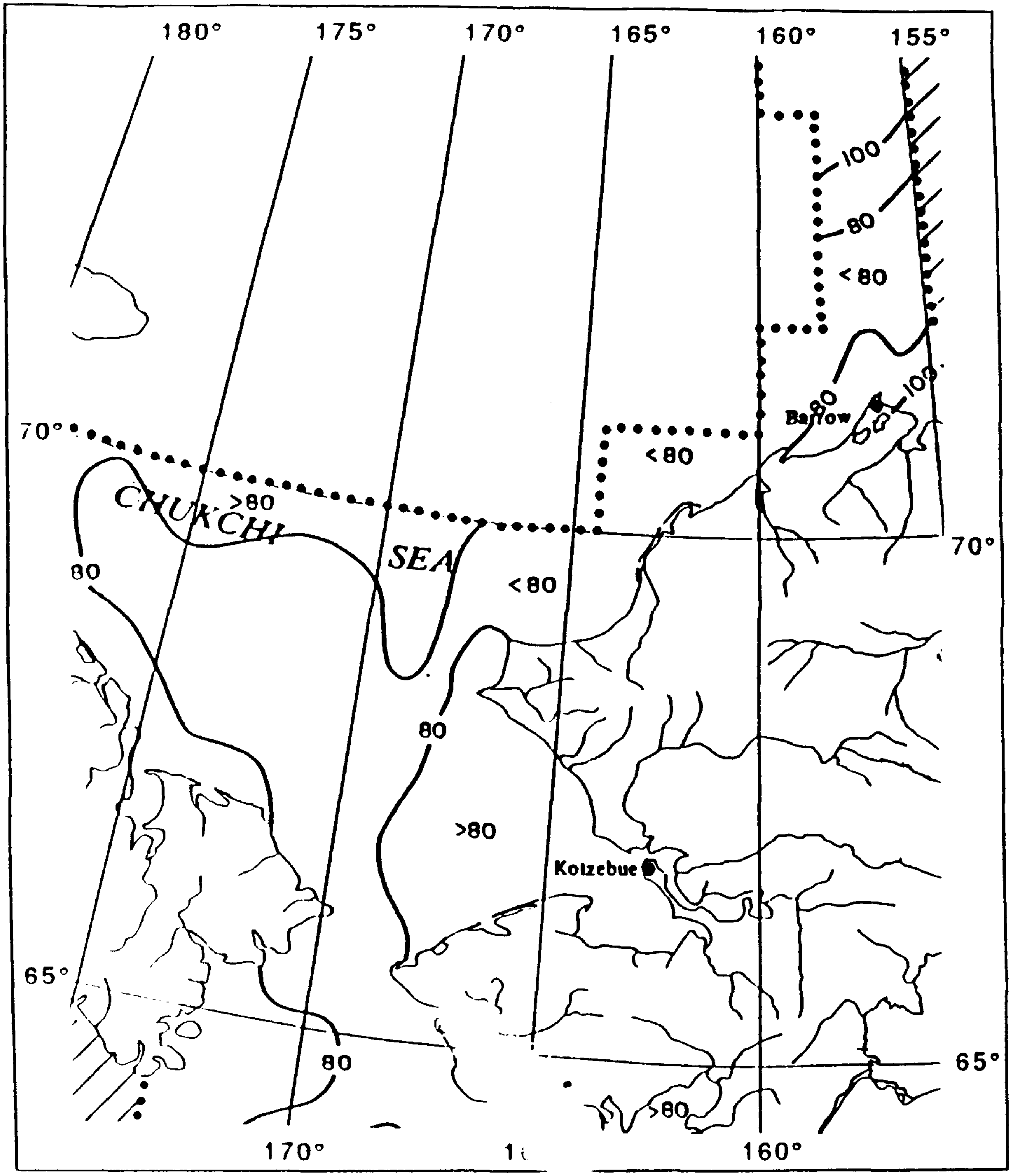


February 16-28

After LaBelle et al. 1983

Figure 37d

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

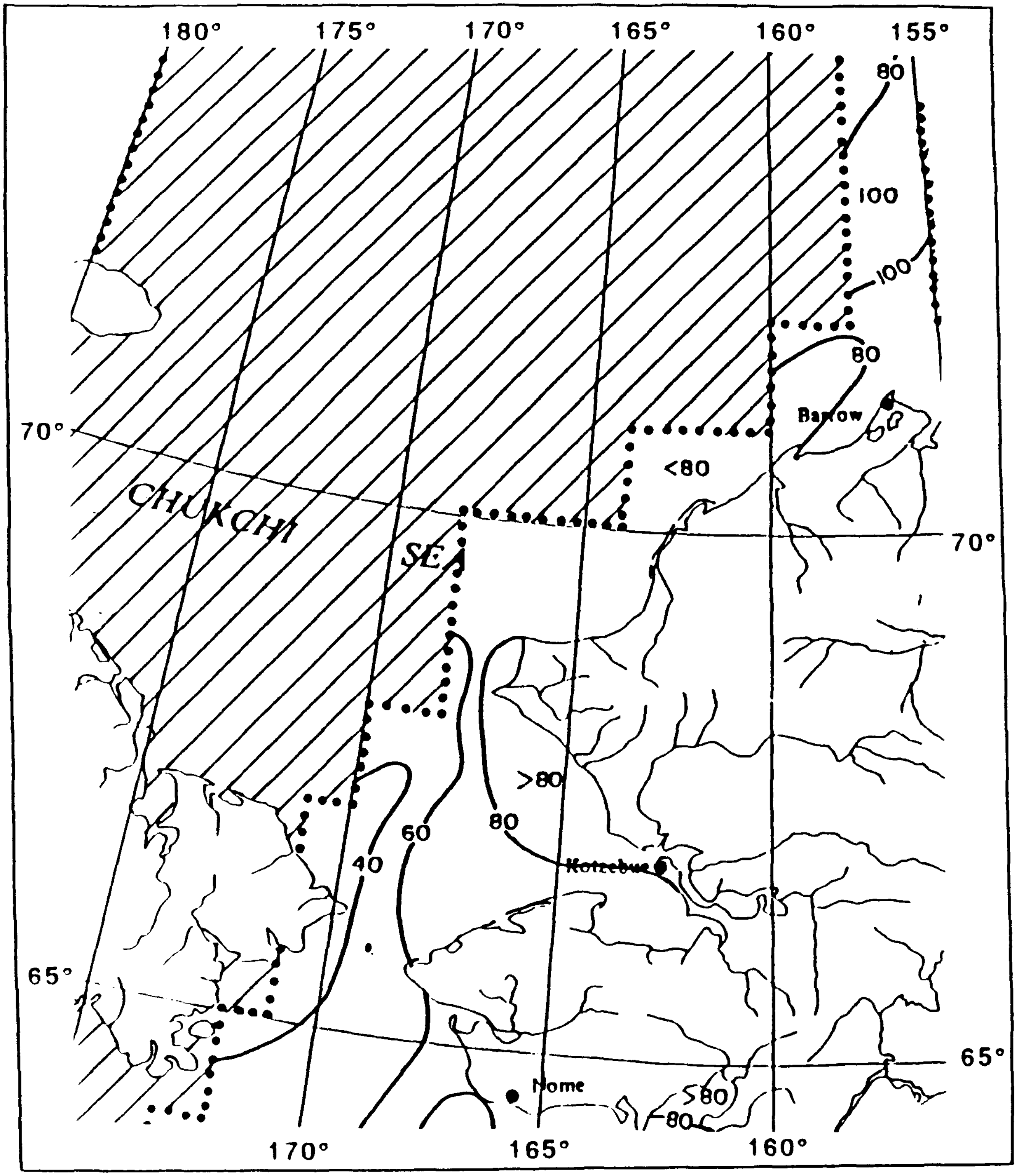


March 1-15

After LaBelle et al. 1983

Figure 37e

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

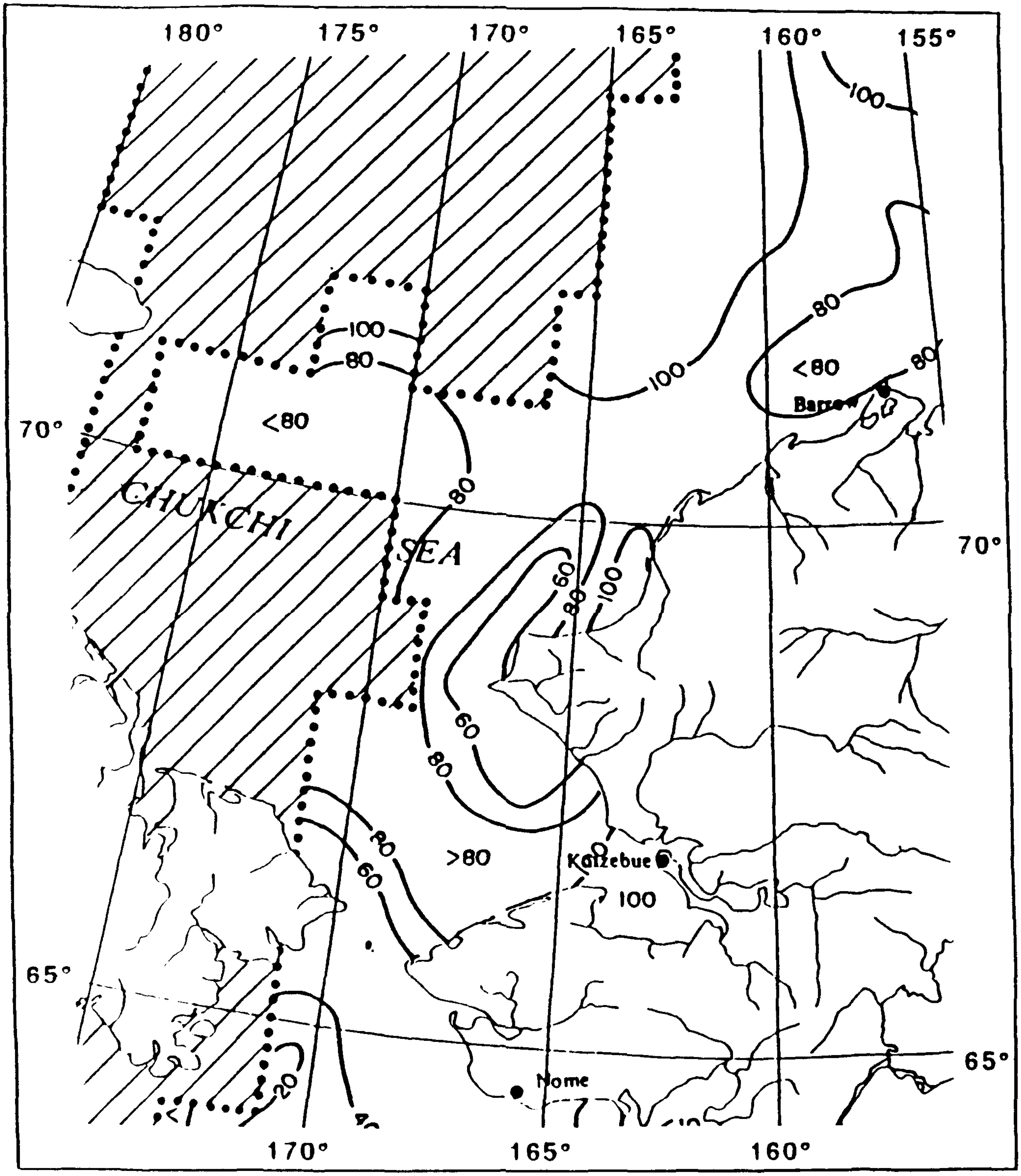


March 16-31

After LaBelle et al. 1983

Figure 37f

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

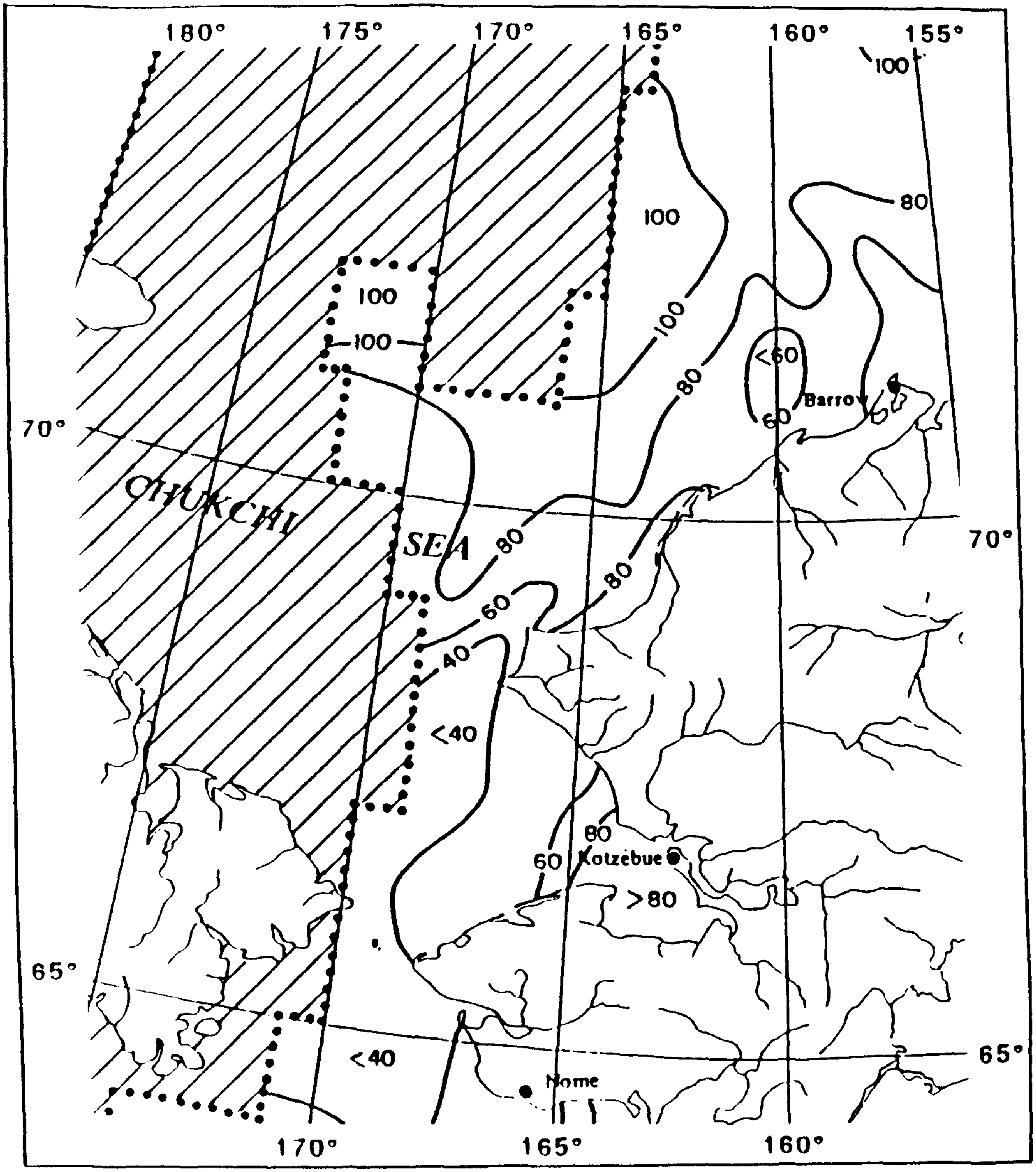


April 1-15

After LaBelle et al. 1983

Figure 37g

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

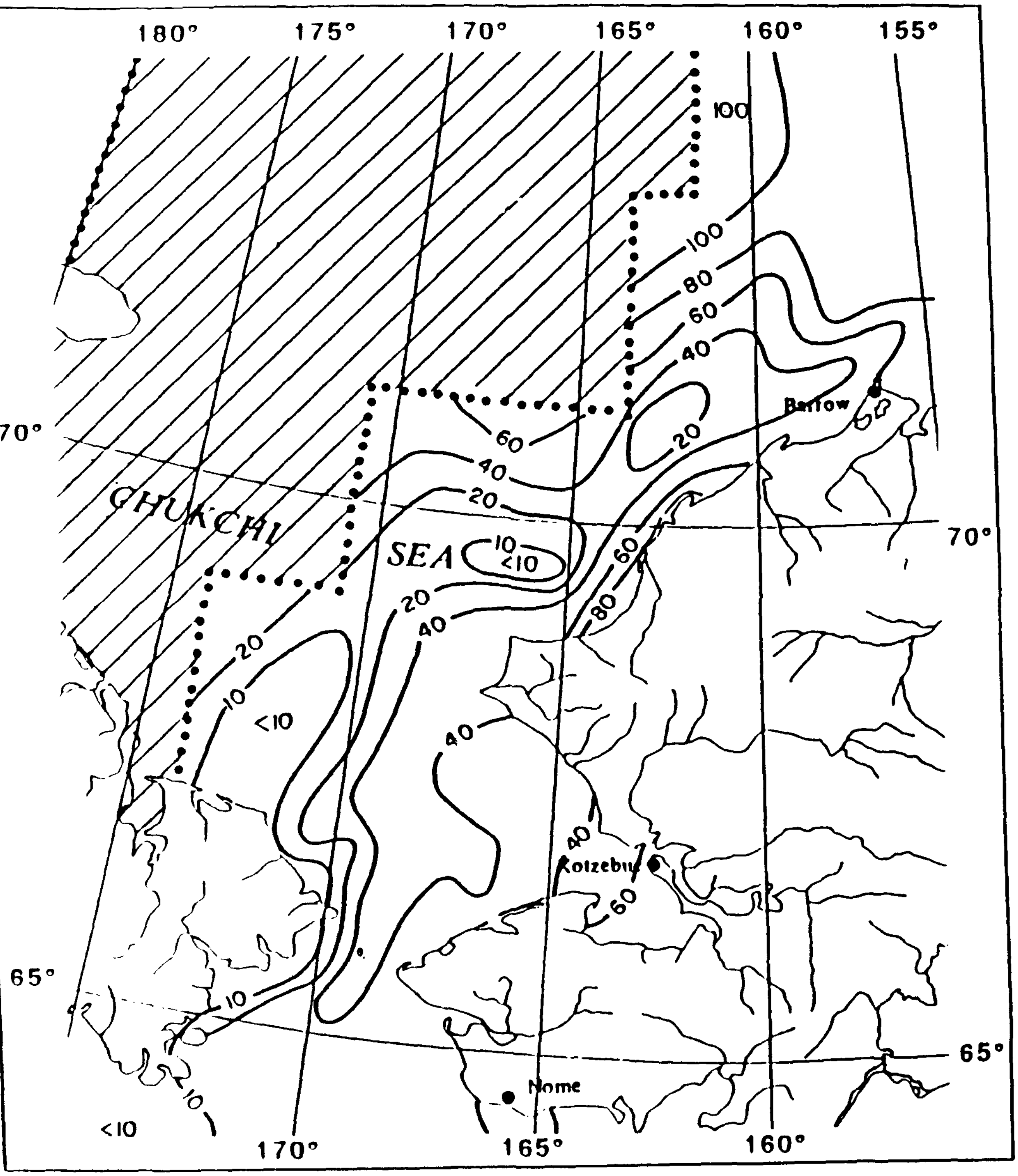


April 16-30

After LaBelle et al. 1983

Figure 37h

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

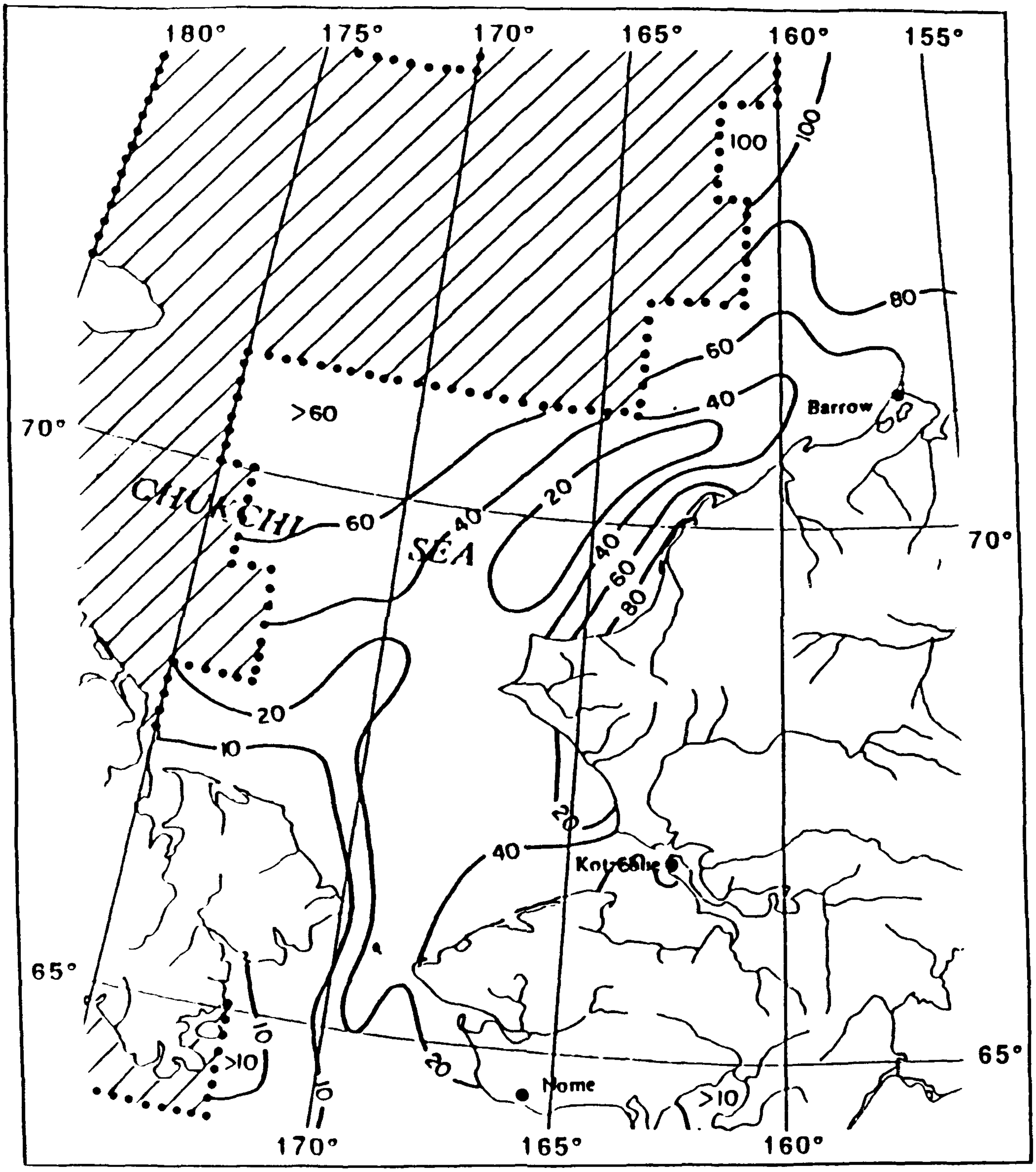


May 1-15

After LaBelle et al. 1983

Figure 37i

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

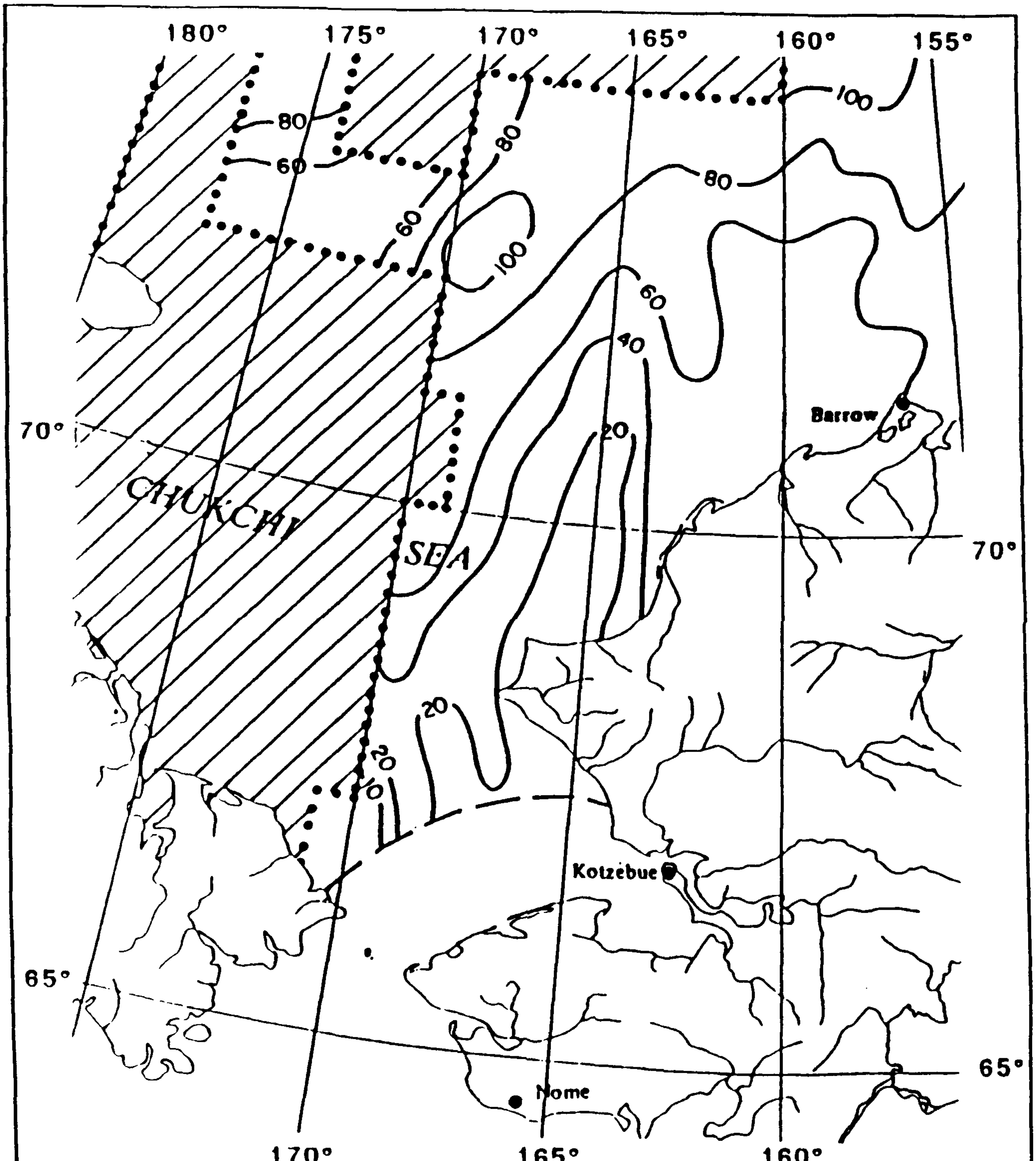


May 16-31

After LaBelle et al. 1983

Figure 37j

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

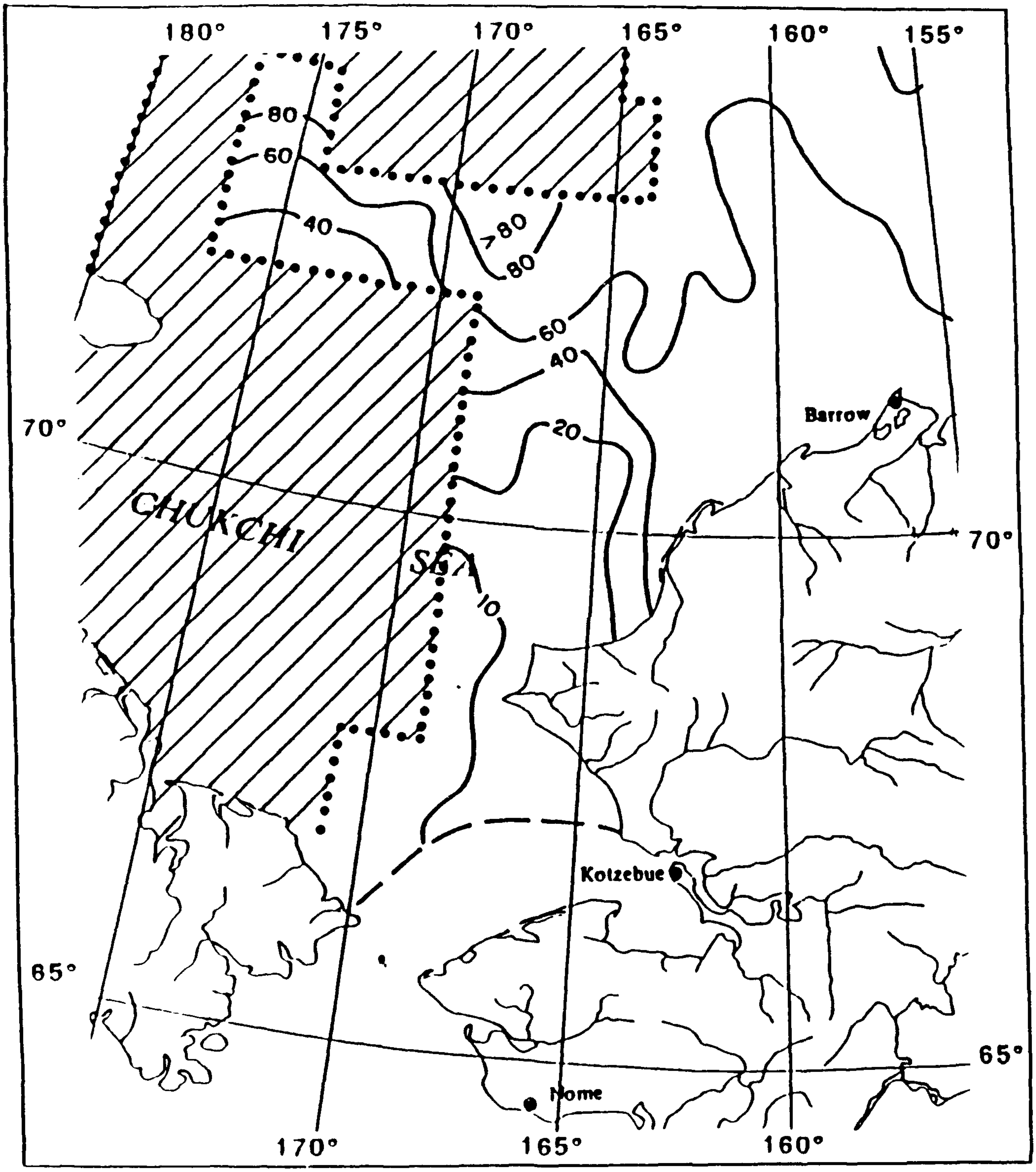


June 1-15

After LaBelle et al. 1983

Figure 37k

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

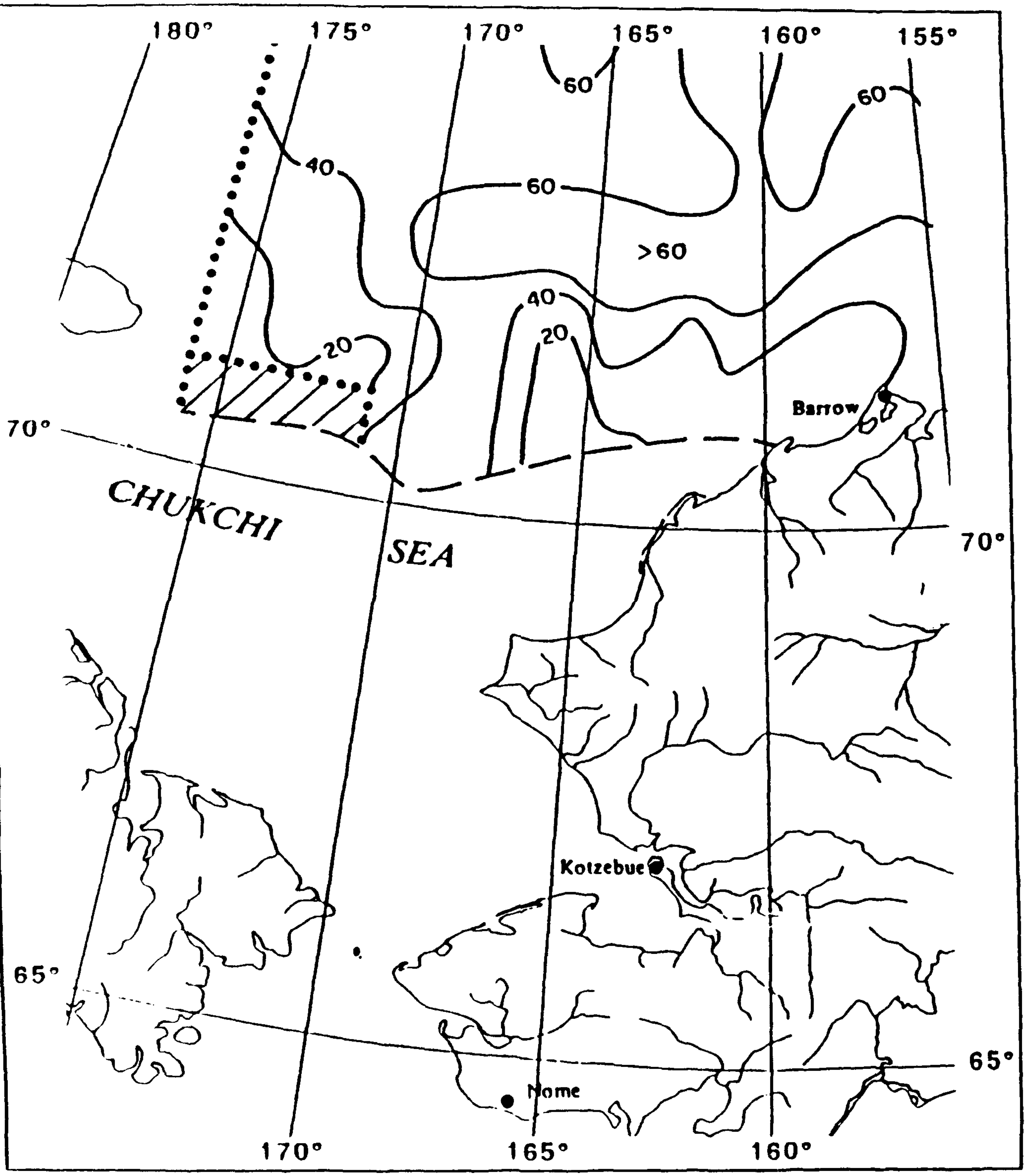


June 16-30

After LaBelle et al. 1983

Figure 371

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

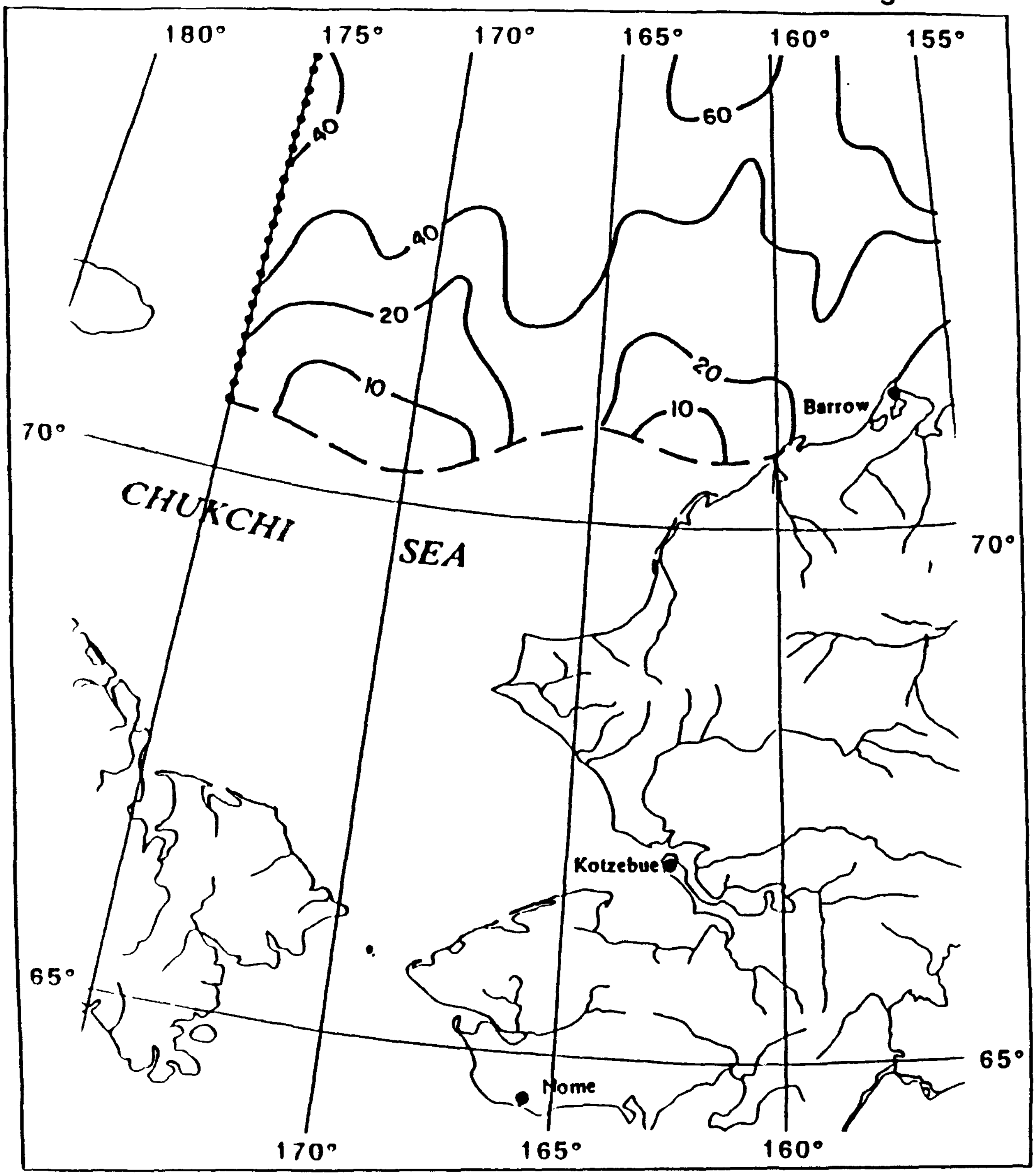


July 1-15

After LaBelle et al. 1983

Figure 37m

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

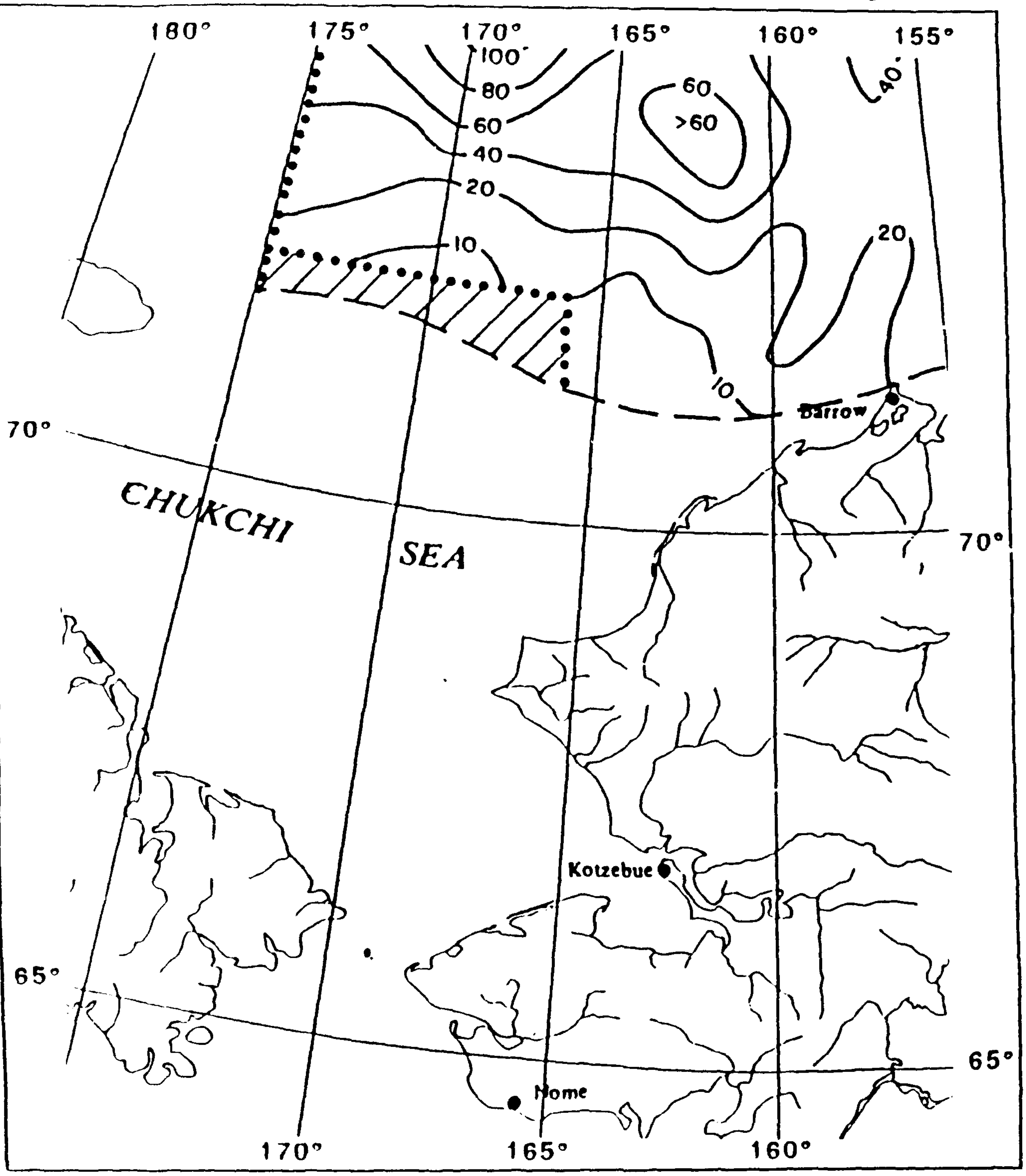


July 16-31

After LaBelle et al. 1983

Figure 37n

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

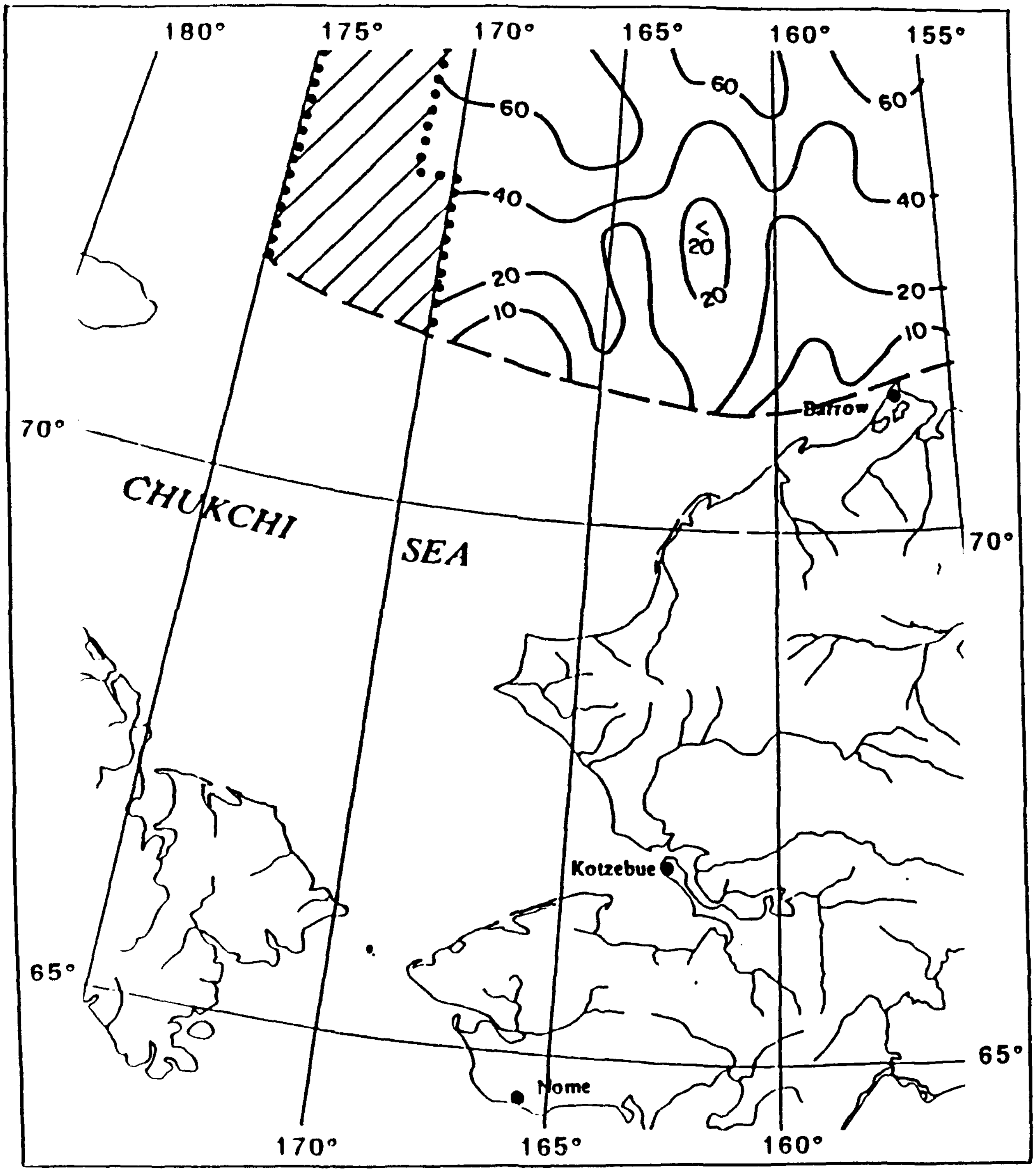


August 1-15

After LaBelle et al. 1983

Figure 37o

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

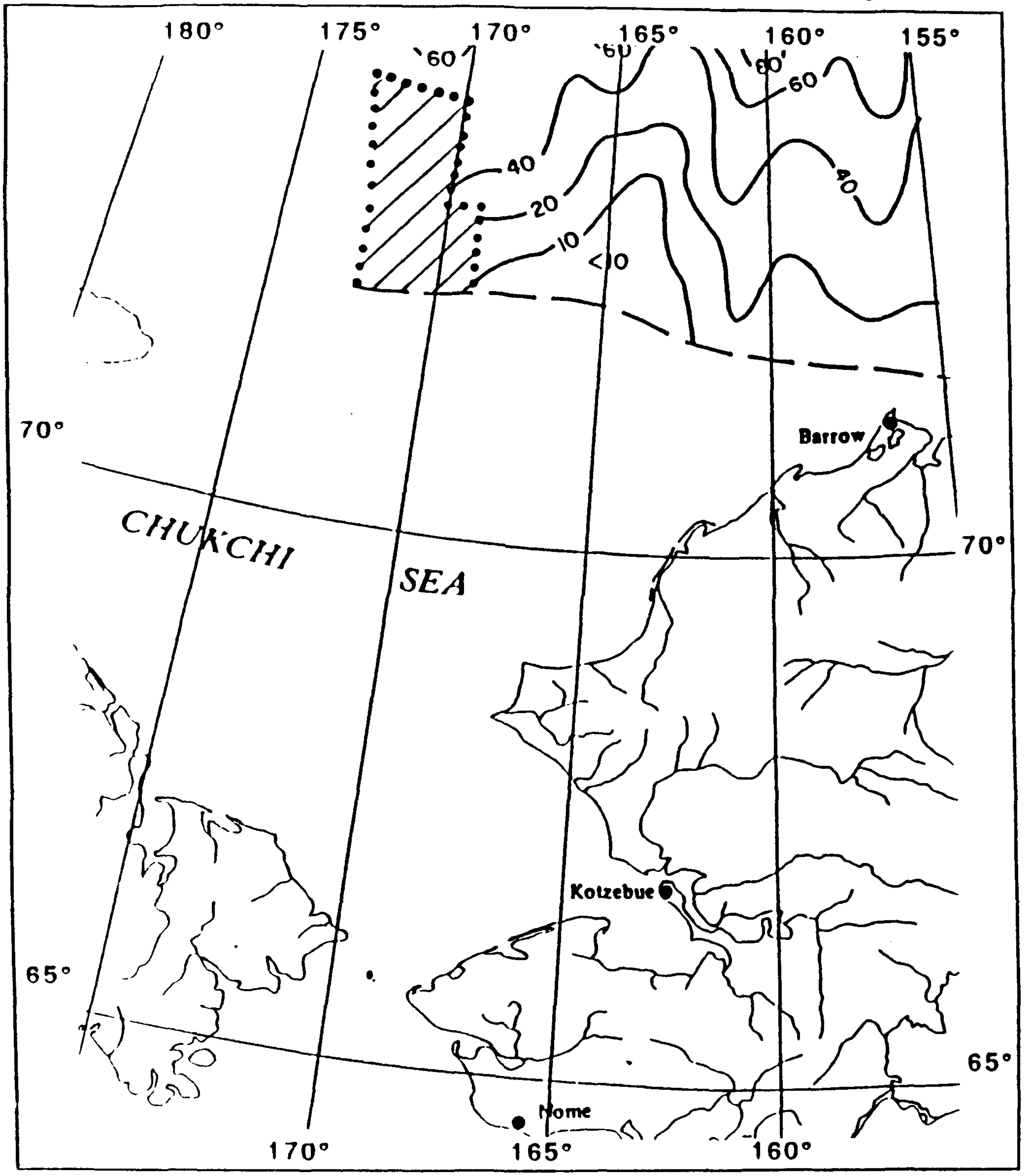


After LaBelle et al. 1983

August 16-31

Figure 37p

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

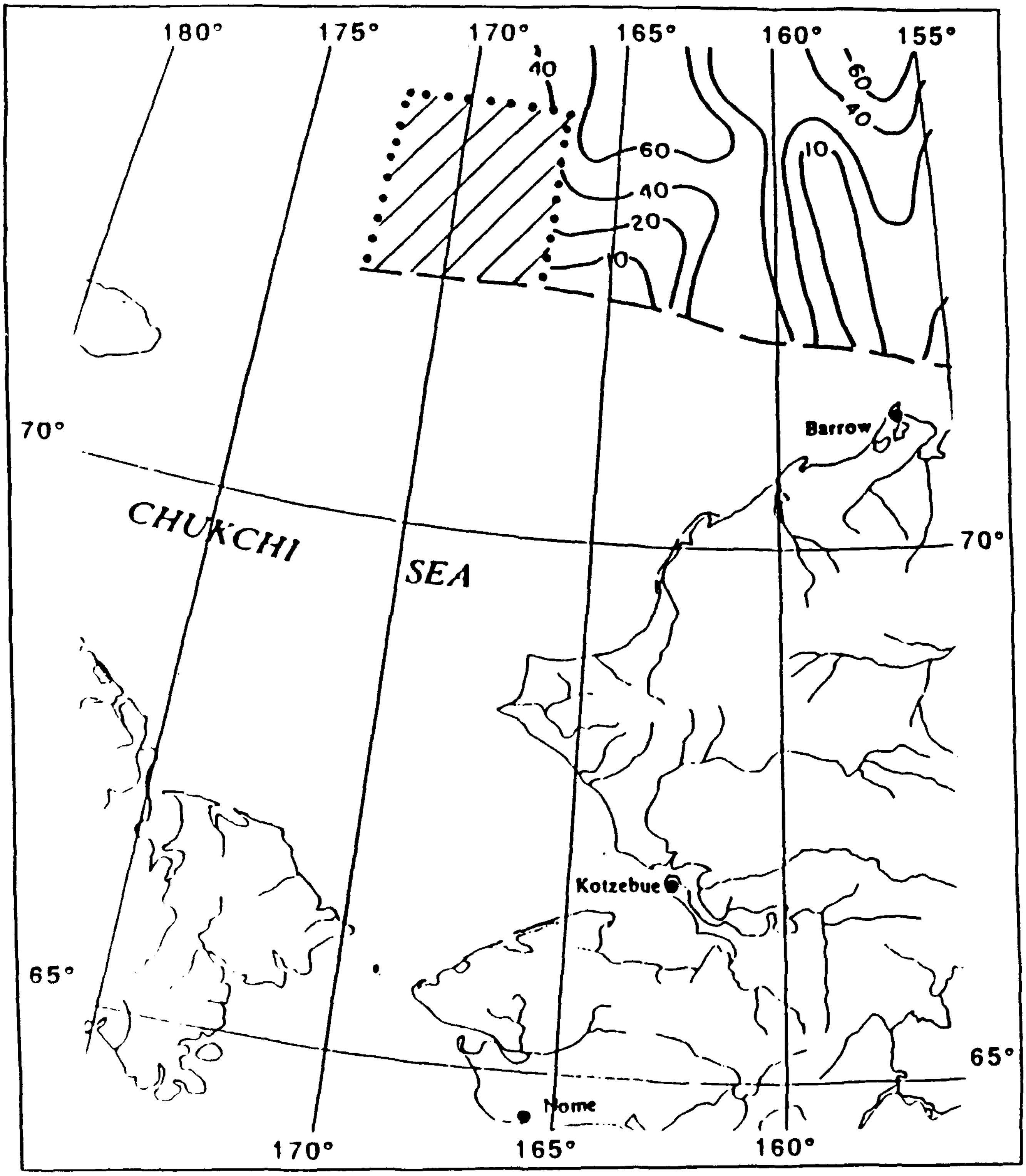


September 1-15

After LaBelle et al. 1983

Figure 37q

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

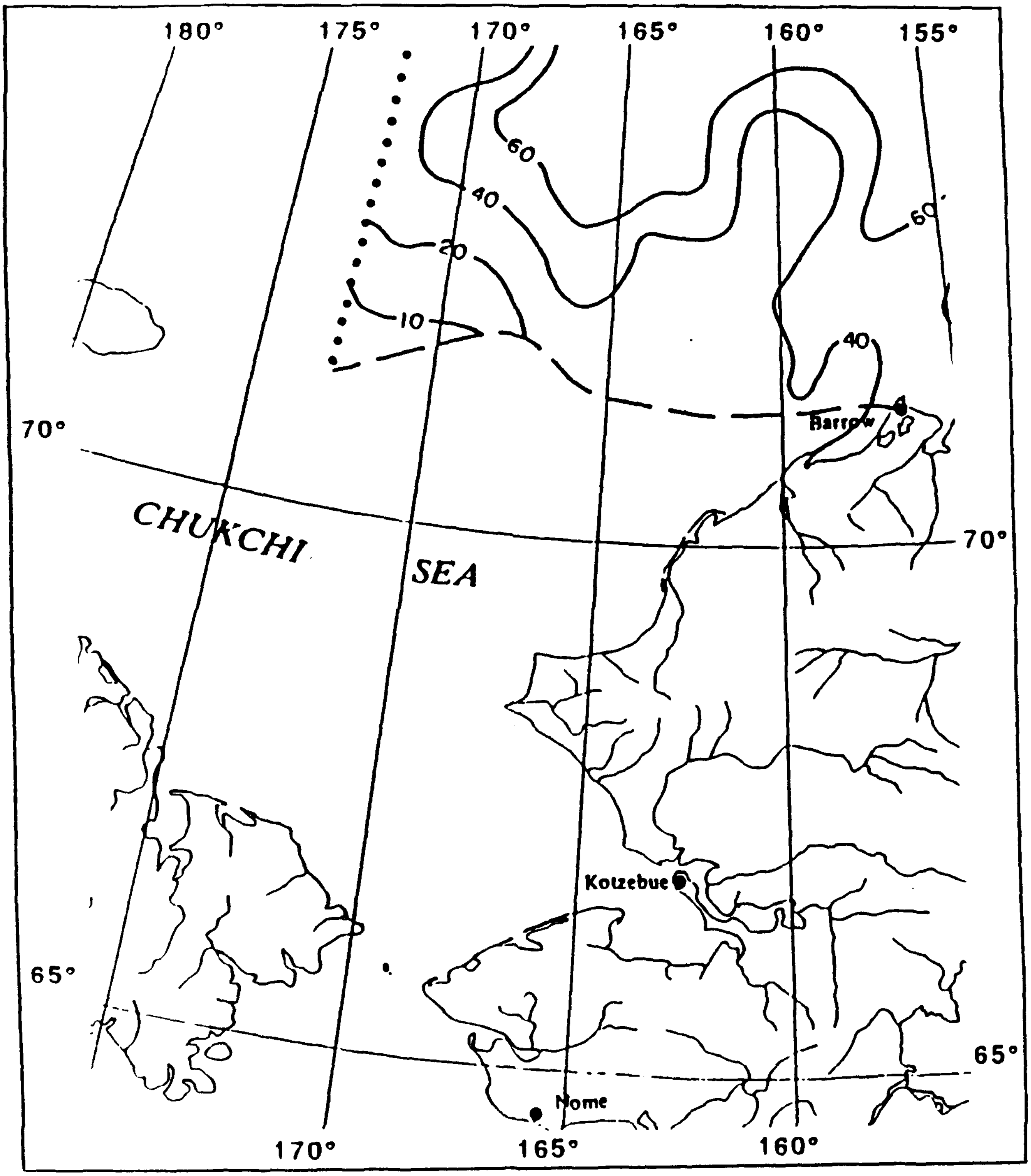


September 16-30

After LaBelle et al. 1983

Figure 37r

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

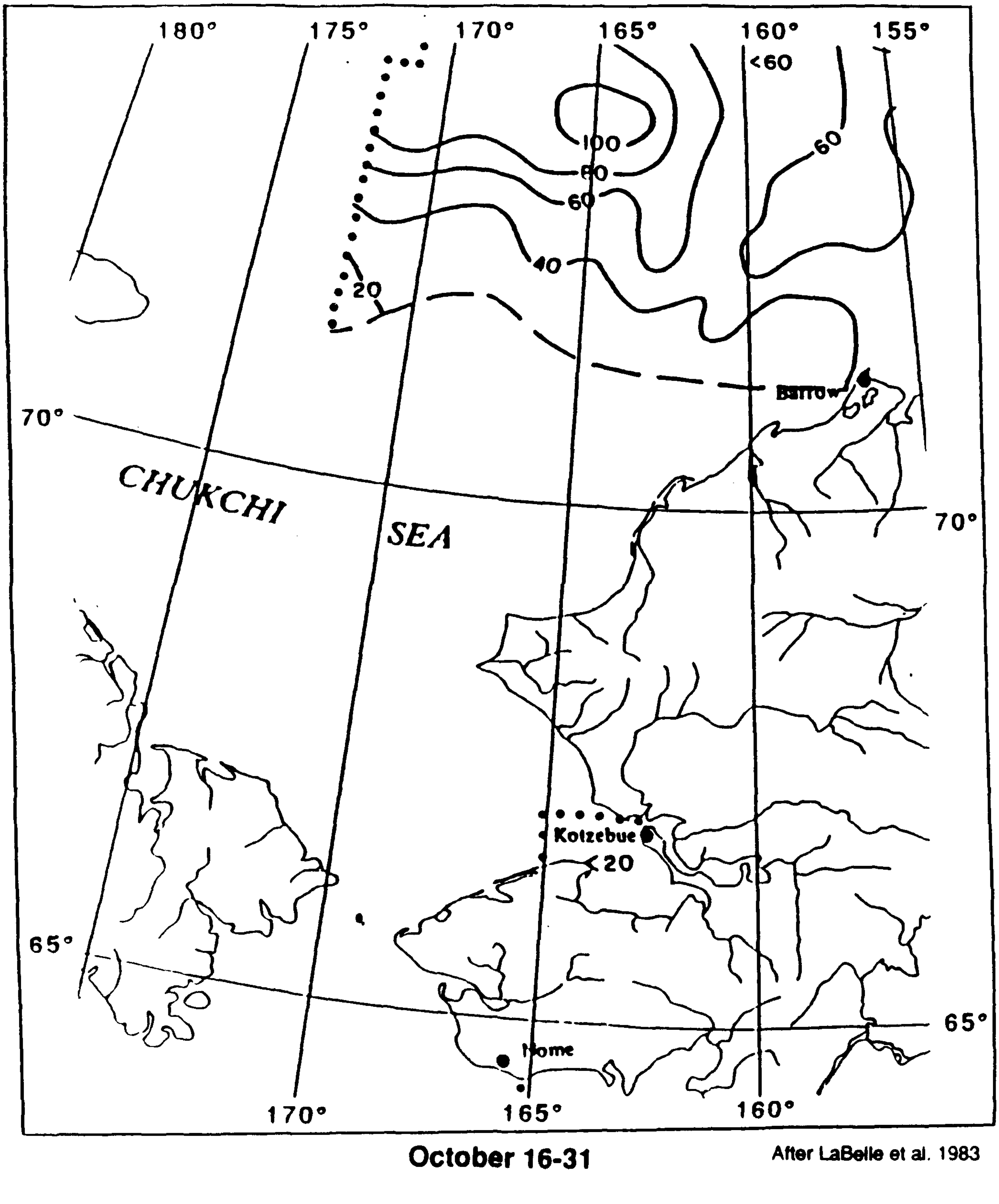


October 1-15

After LaBelle et al. 1983

Figure 37s

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

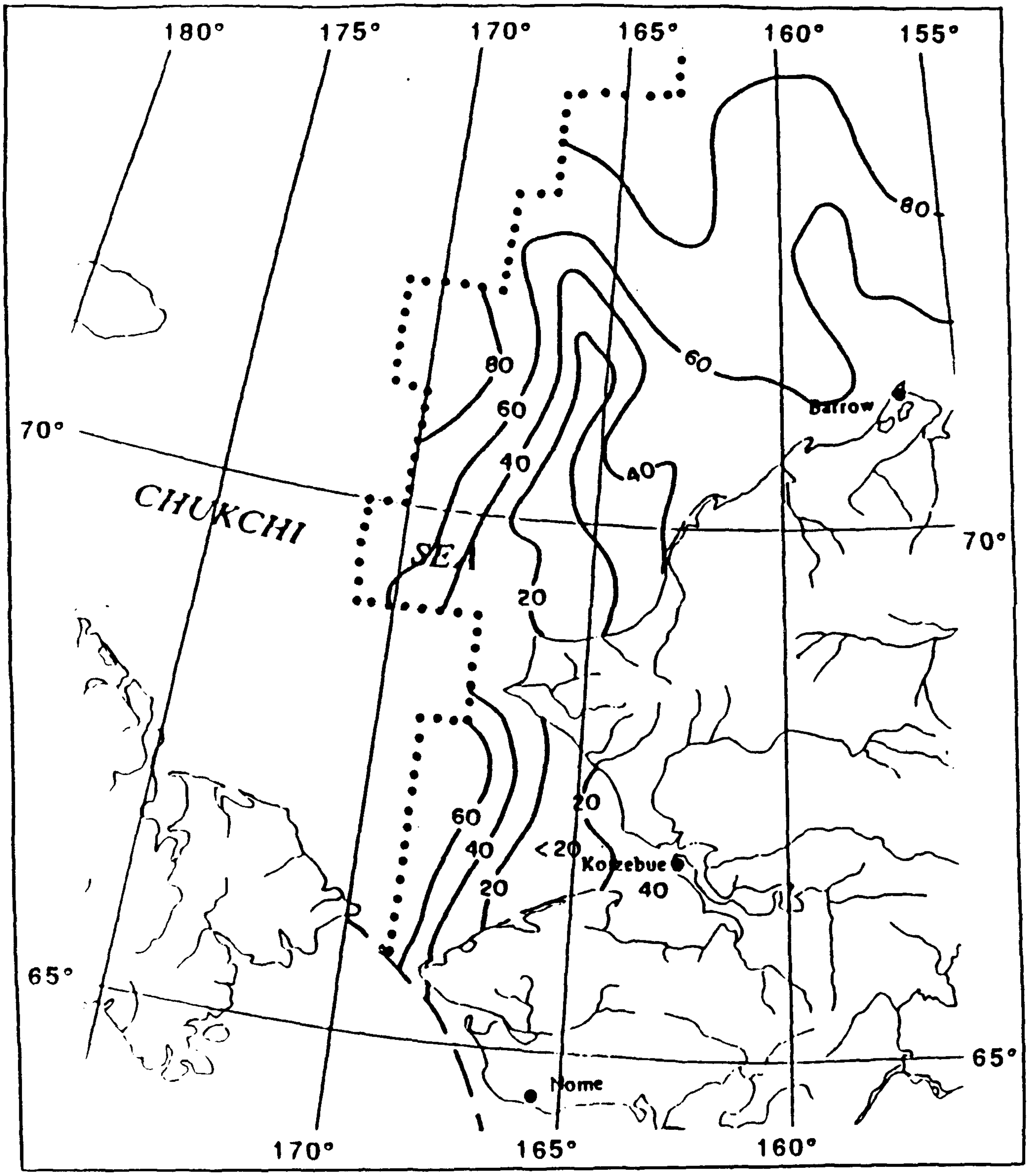


October 16-31

After LaBelle et al. 1983

Figure 37t

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

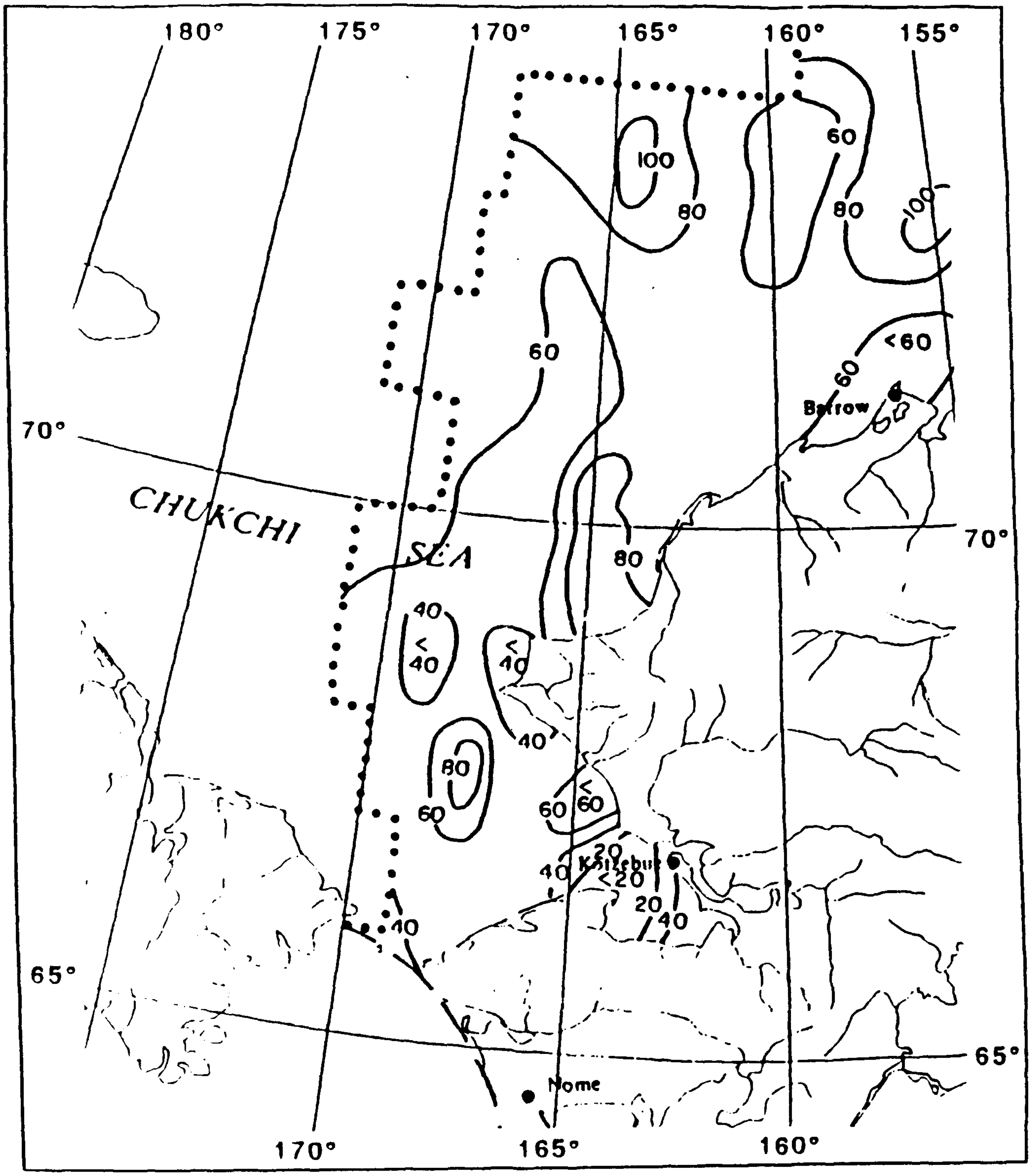


November 1-15

After LaBelle et al. 1983

Figure 37u

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

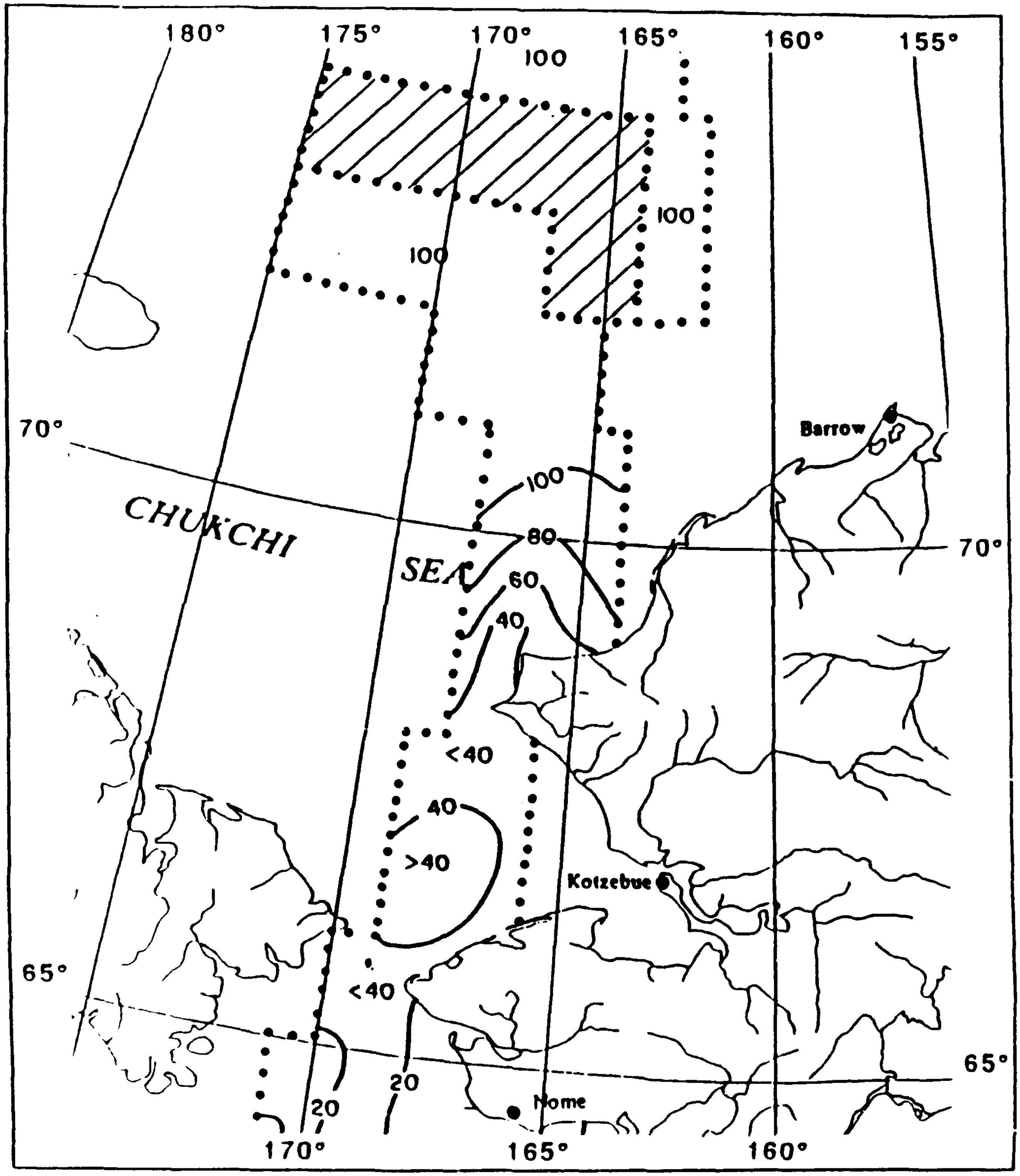


November 16-30

After LaBelle et al. 1983

Figure 37v

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

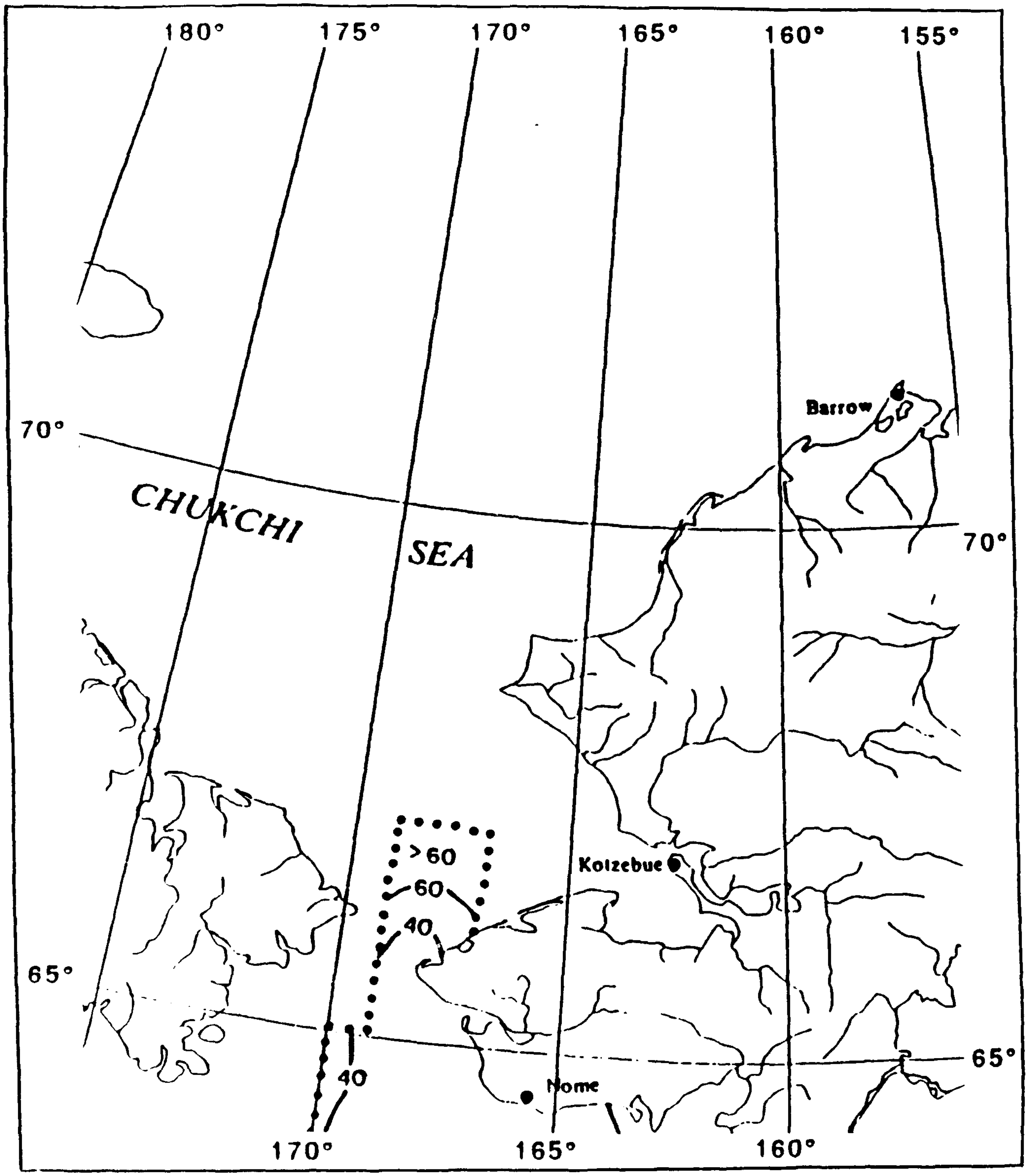


December 1-15

After LaBelle et al. 1983

Figure 37w

Ice Floes Larger than 500 m (1640 ft), in Percent Coverage

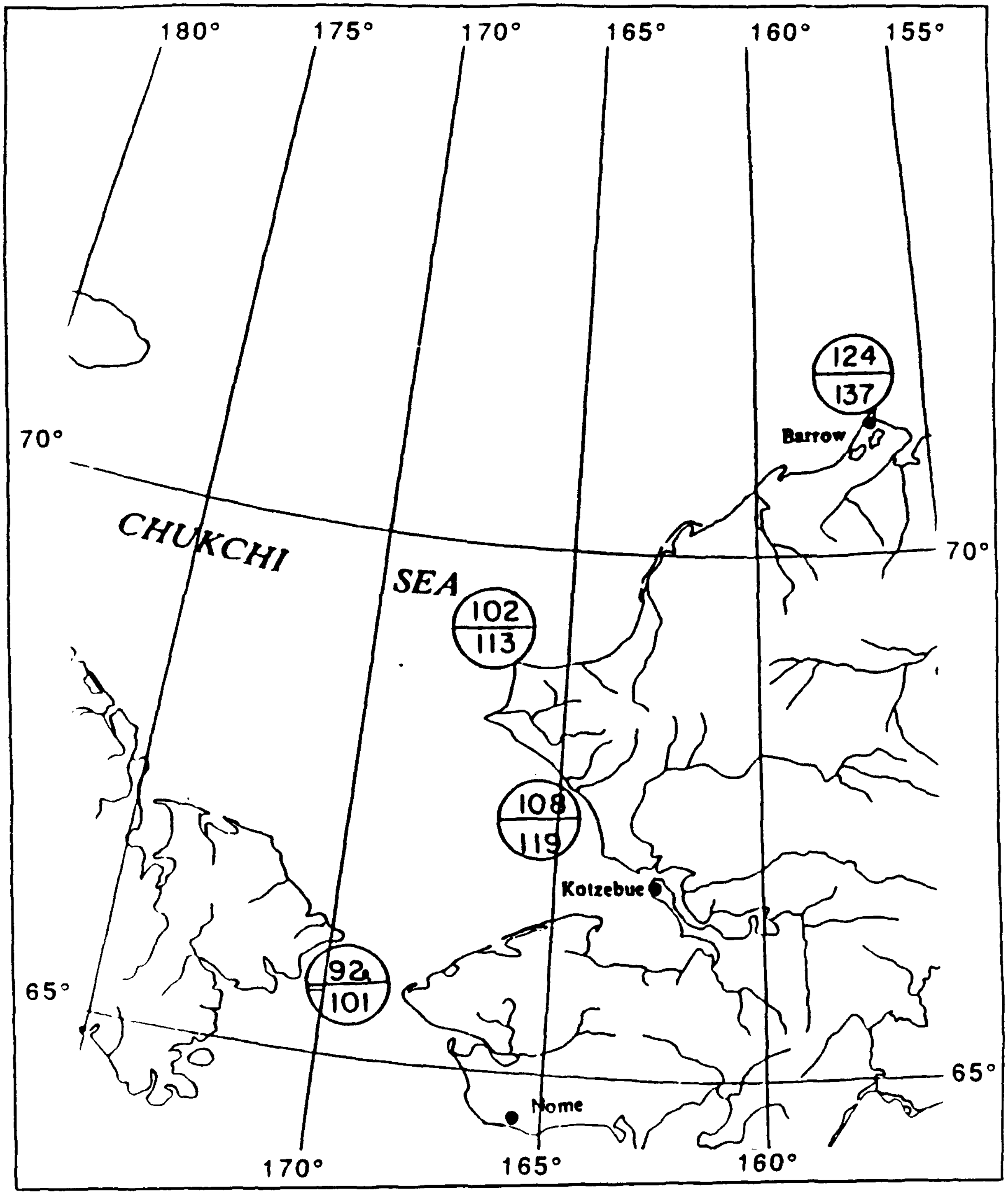


December 16-31

After LaBelle et al. 1983

Figure 37x

Calculated Ice Thickness (cm)

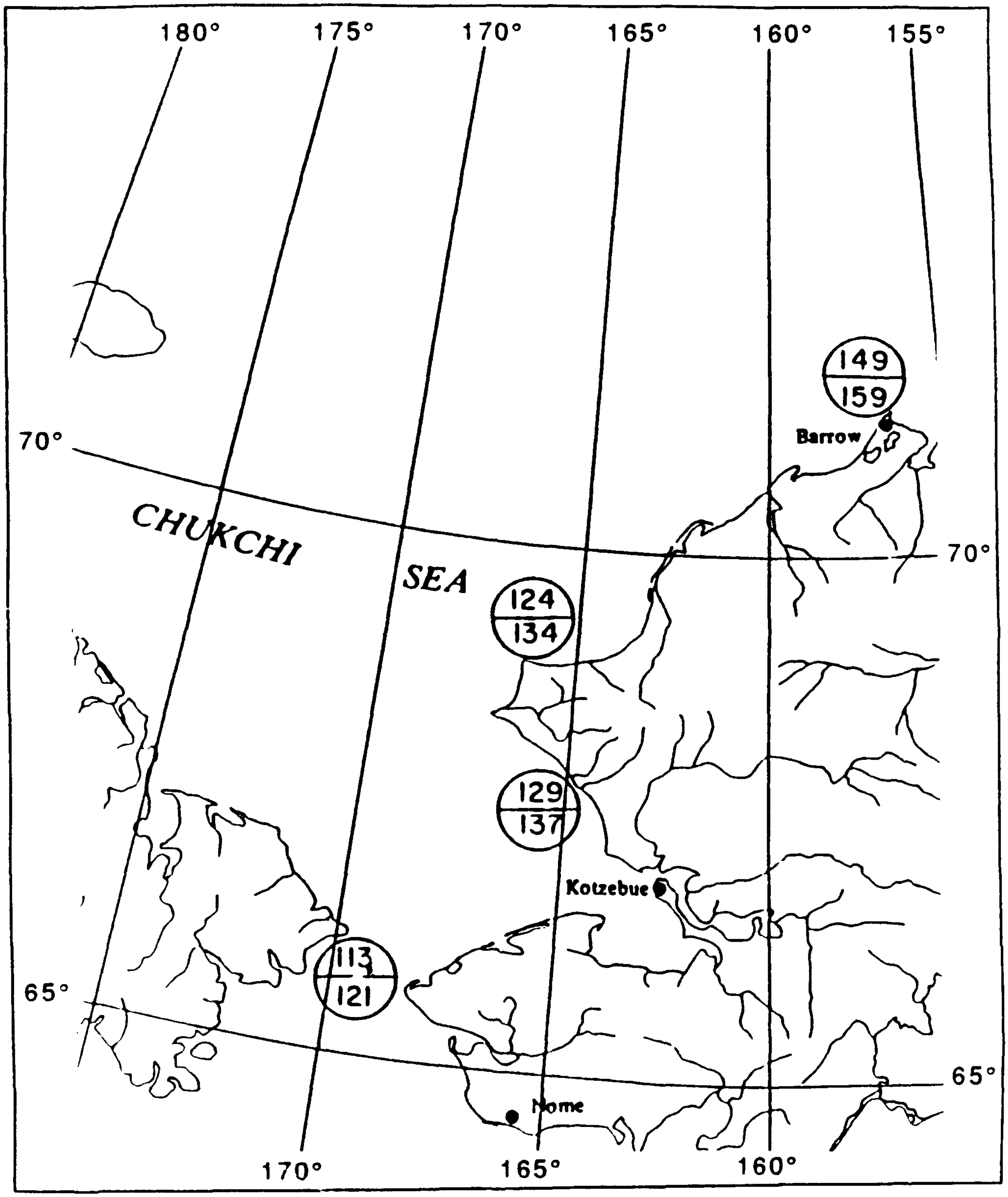


January 31

After LaBelle et al. 1983

Figure 38a

Calculated Ice Thickness (cm)

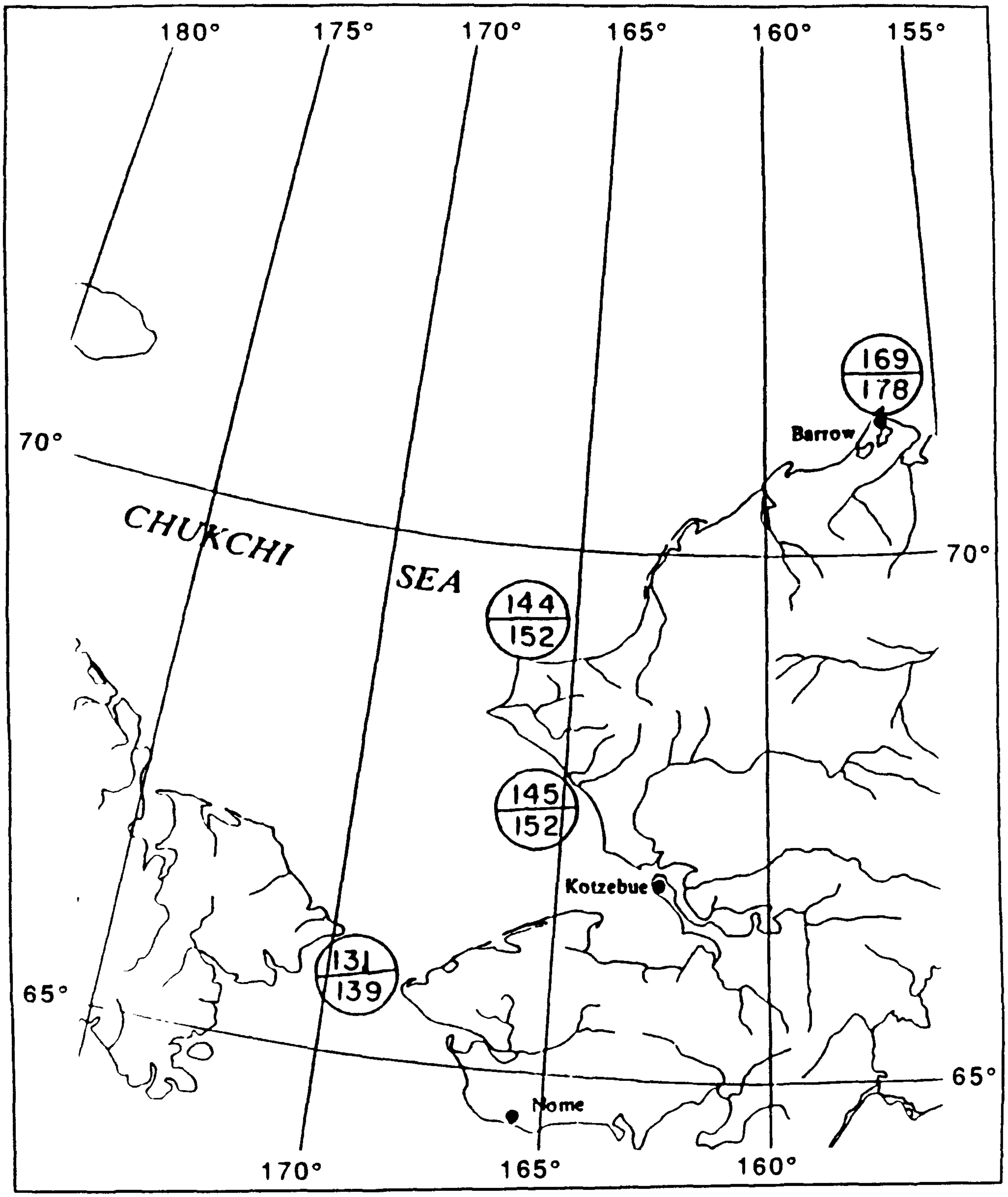


February 28

After LaBelle et al. 1983

Figure 38b

Calculated Ice Thickness (cm)

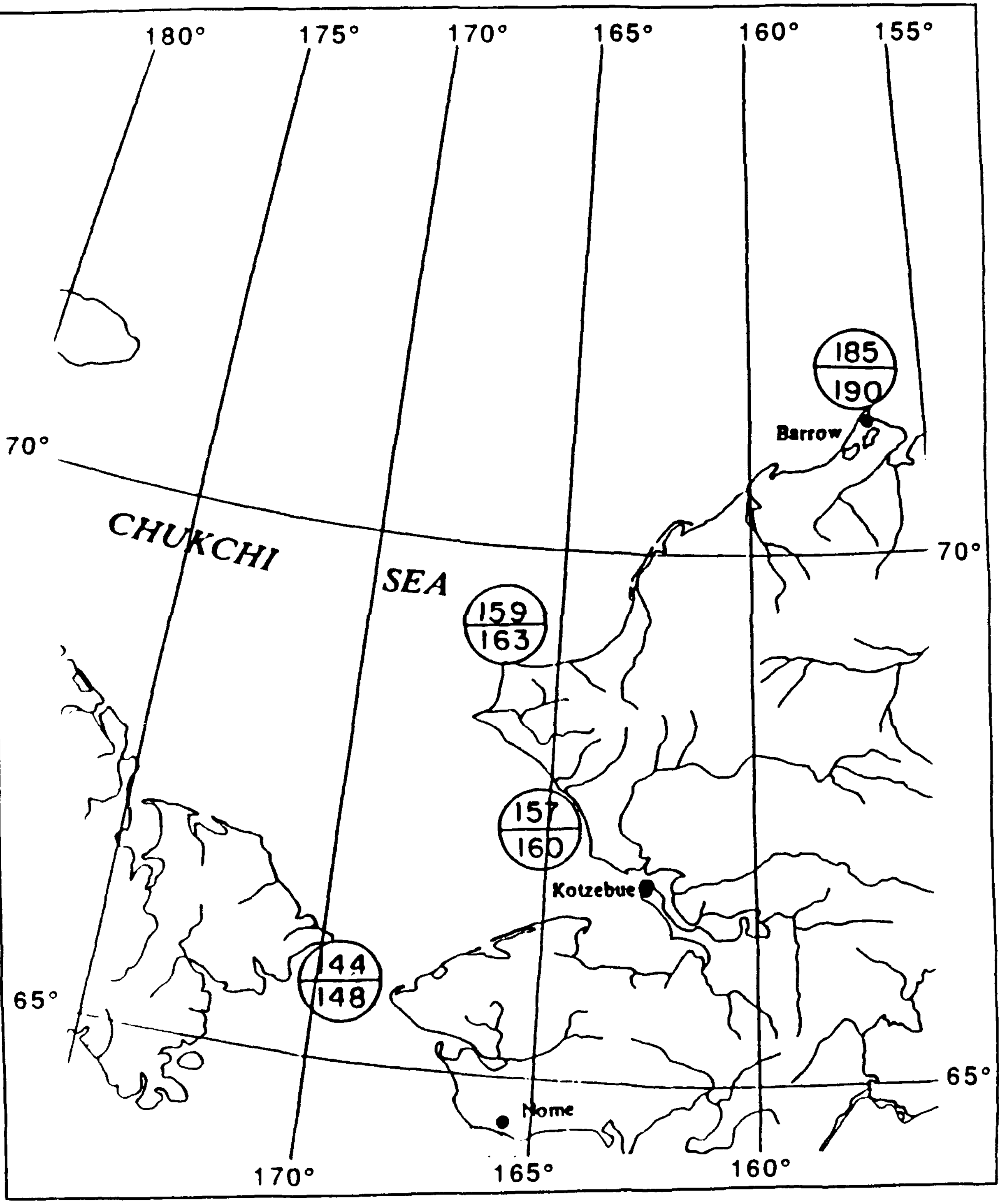


March 31

After LaBelle et al. 1983

Figure 38c

Calculated Ice Thickness (cm)

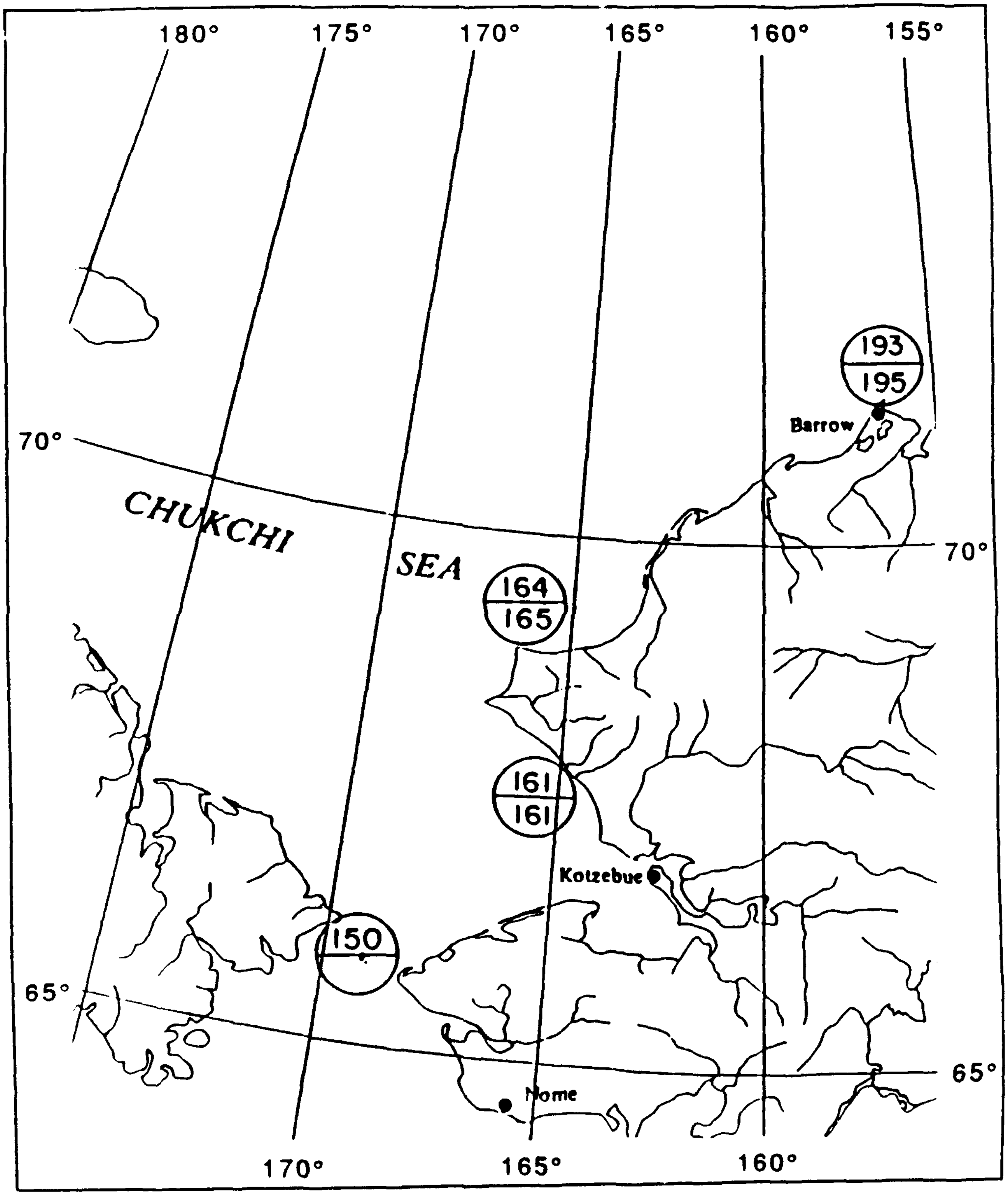


April 30

After LaBelle et al. 1983

Figure 38d

Calculated Ice Thickness (cm)

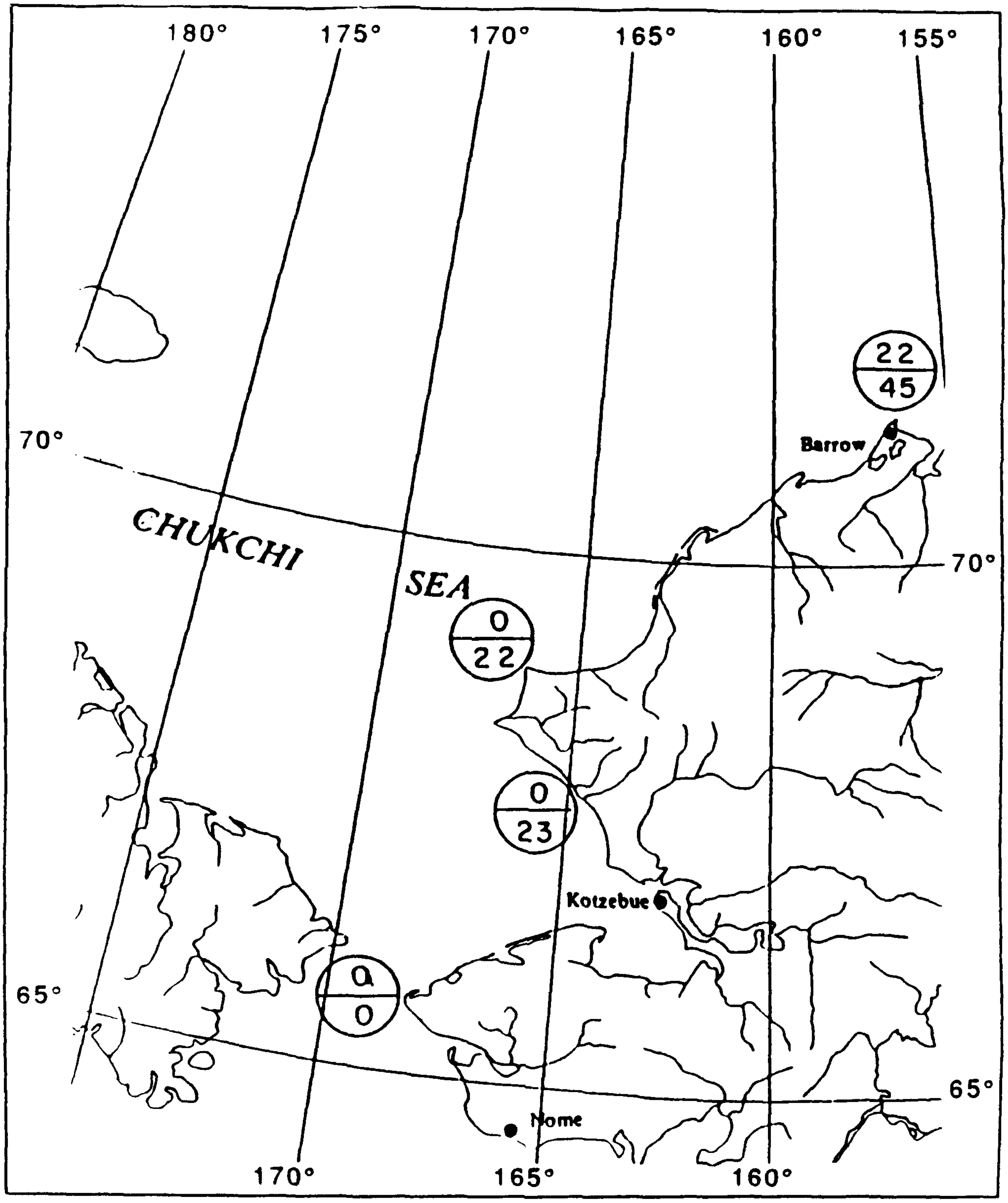


May 31

After LaBelle et al. 1983

Figure 38e

Calculated Ice Thickness (cm)

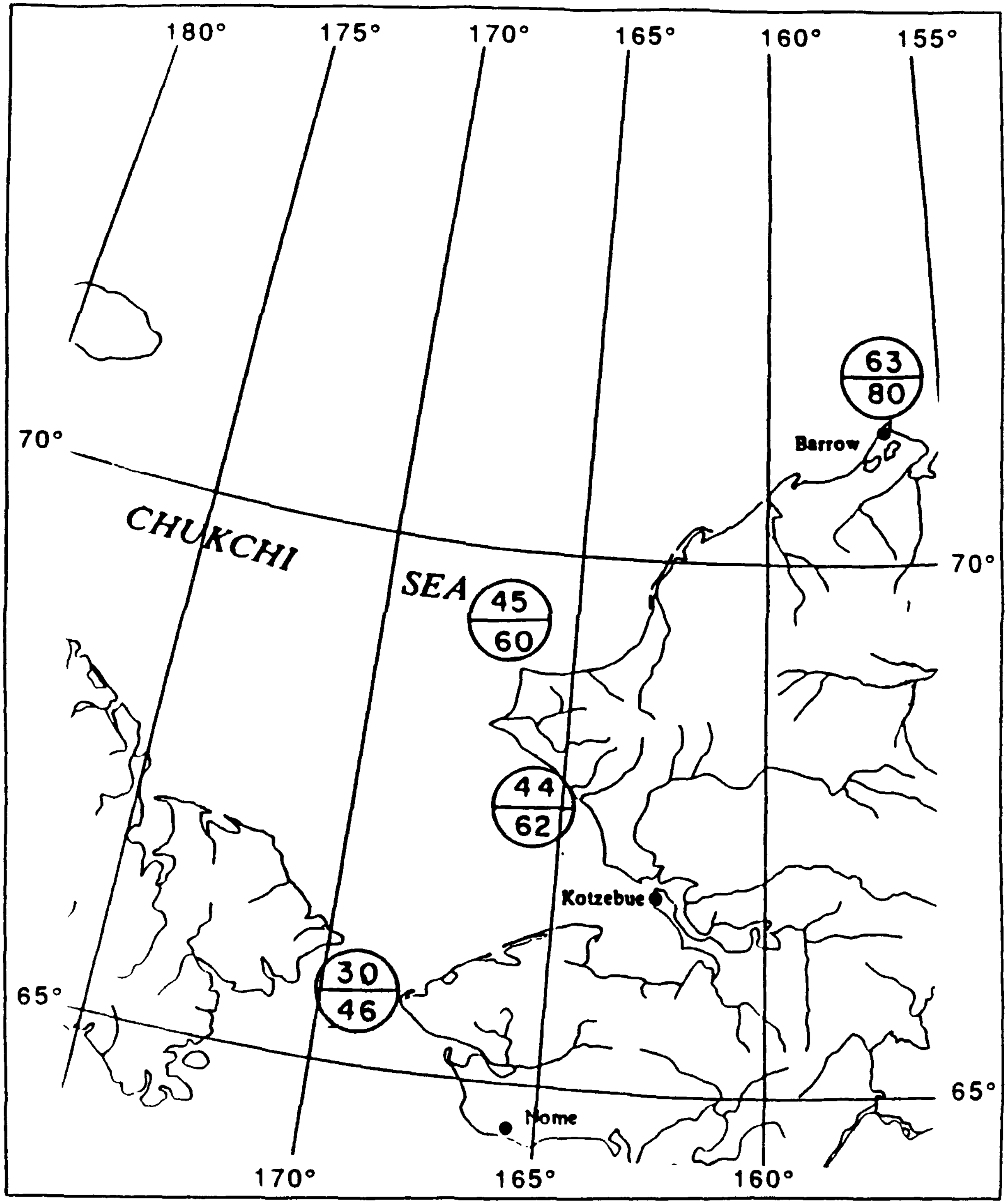


October 31

After LaBelle et al. 1983

Figure 38f

Calculated Ice Thickness (cm)

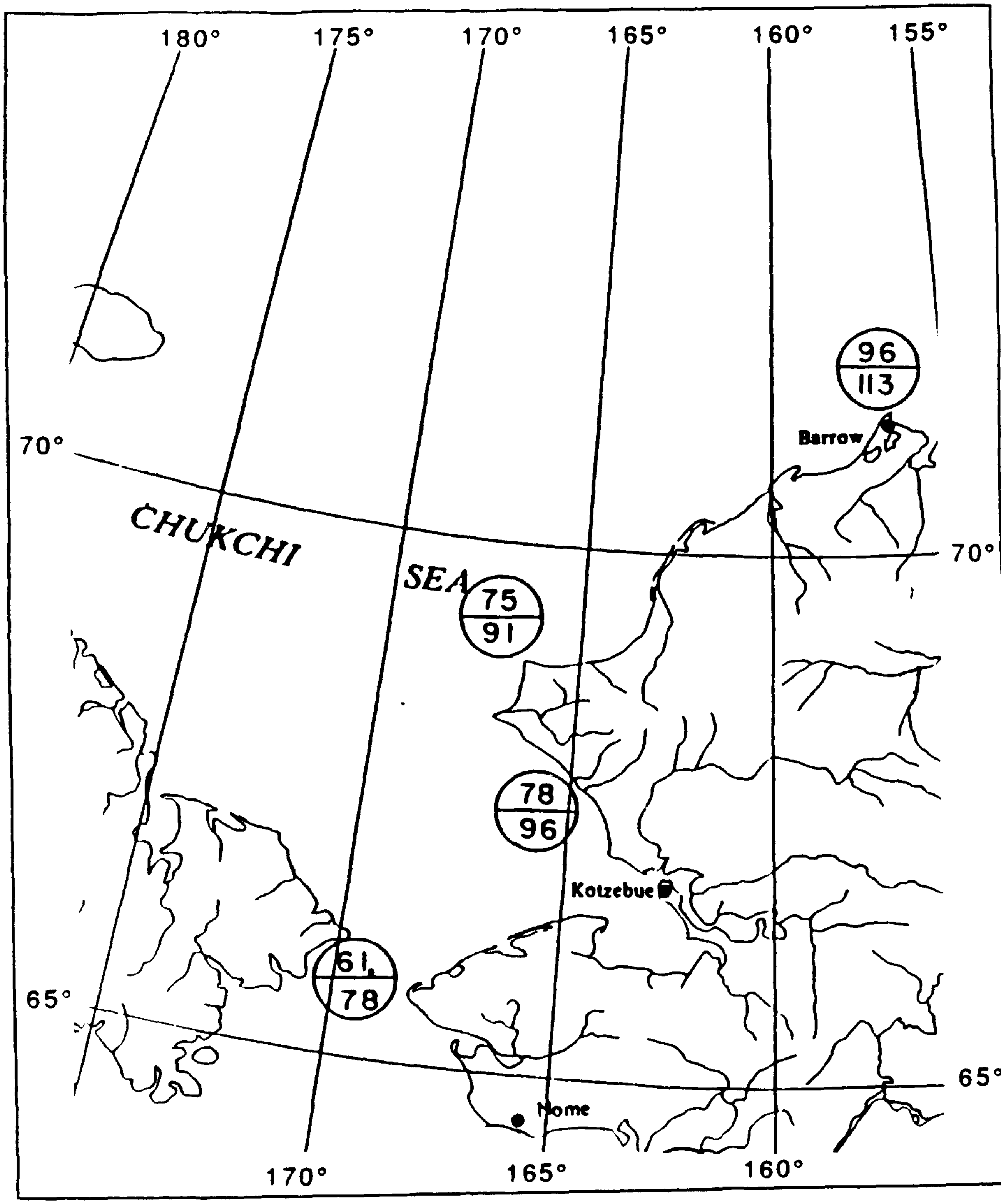


November 30

After LaBelle et al. 1983

Figure 38g

Calculated Ice Thickness (cm)



December 31

After LaBelle et al. 1983

Figure 38h

RECURRING LEADS AND POLYNYAS

Wind and current stresses on the ice can cause compression or divergence and open relatively narrow, long stretches of open water in an otherwise dense ice cover. In the absence of strong currents, the wind induces leads which run perpendicular to the wind direction. Flaw leads generally occur just seaward of the stable fast ice zone when strong offshore winds develop. The most notable flaw lead event along the Chukchi Sea coast of Alaska is the series of leads which opens each spring and allows whales to reach the Beaufort Sea. Leads open in response to easterly winds that usually occur in March or April.

An area of open water or thin ice is a common occurrence in the Point Hope vicinity (Carleton 1980) but the areal extent varies considerably from year to year (figure 39). This area is not necessarily a true polynya. in the early spring, any open water is often refrozen by the cold offshore winds which cause polynya formation. Furthermore, the opening can be very quickly closed by a reversal in the wind field. Therefore, although this area commonly experiences open water or light ice conditions, these circumstances cannot be anticipated with any degree of certainty (AEIDC 1974).

NEARSHORE FAST ICE BOUNDARY

Figures 40a and 40b show the seasonal fast ice boundary from the work of Stringer, Barrett, and Schreurs (1980), performed for the National Oceanic and Atmospheric Administration, Outer Continental Shelf *Environmental Assessment* Program (OCSEAP). The objective of this project was to develop a description of nearshore ice along the Bering, Chukchi, and Beaufort coasts and to identify those features that may be a hazard to oil and gas development. LANDSAT imagery was used to develop regional maps for each year of the study. These yearly regional maps were used to determine average or typical conditions that were then recorded on seasonal maps. Information displayed on the seasonal maps was developed from winter and spring observations for the years 1973 through 1977.

In presenting these data, Stringer, Barrett, and Schreurs (1980) noted that the fast ice zone can vary by tens of kilometers from year to year, month to month, or place to place. This is certainly shown off the northern Chukchi and the Beaufort coast (figure 41). In this area the fast ice boundary has been observed to range from the 20-m isobath to a point 30 to 40 km (20-25 mi) seaward. These extensions appear to be caused by an absence of winds, currents, and internal forces within the ice sheet that normally keep individual floes within the pack ice from freezing together. They noted that these calm conditions can persist for several weeks before sufficient forces exist for failure to take place along lines considerably closer to shore.

According to the World Meteorological Organization Sea Ice Nomenclature definition, fast ice includes all ice that has become attached to the shore, even multi-year pack ice. Therefore, the fast ice boundary displayed extends from a few meters to many kilometers from the coast and is not necessarily bounded by the shear ridge zone.

Chukchi Sea-Point Hope Recurring Flaw Polynya, 1973, 74, 75, 1976, 77.

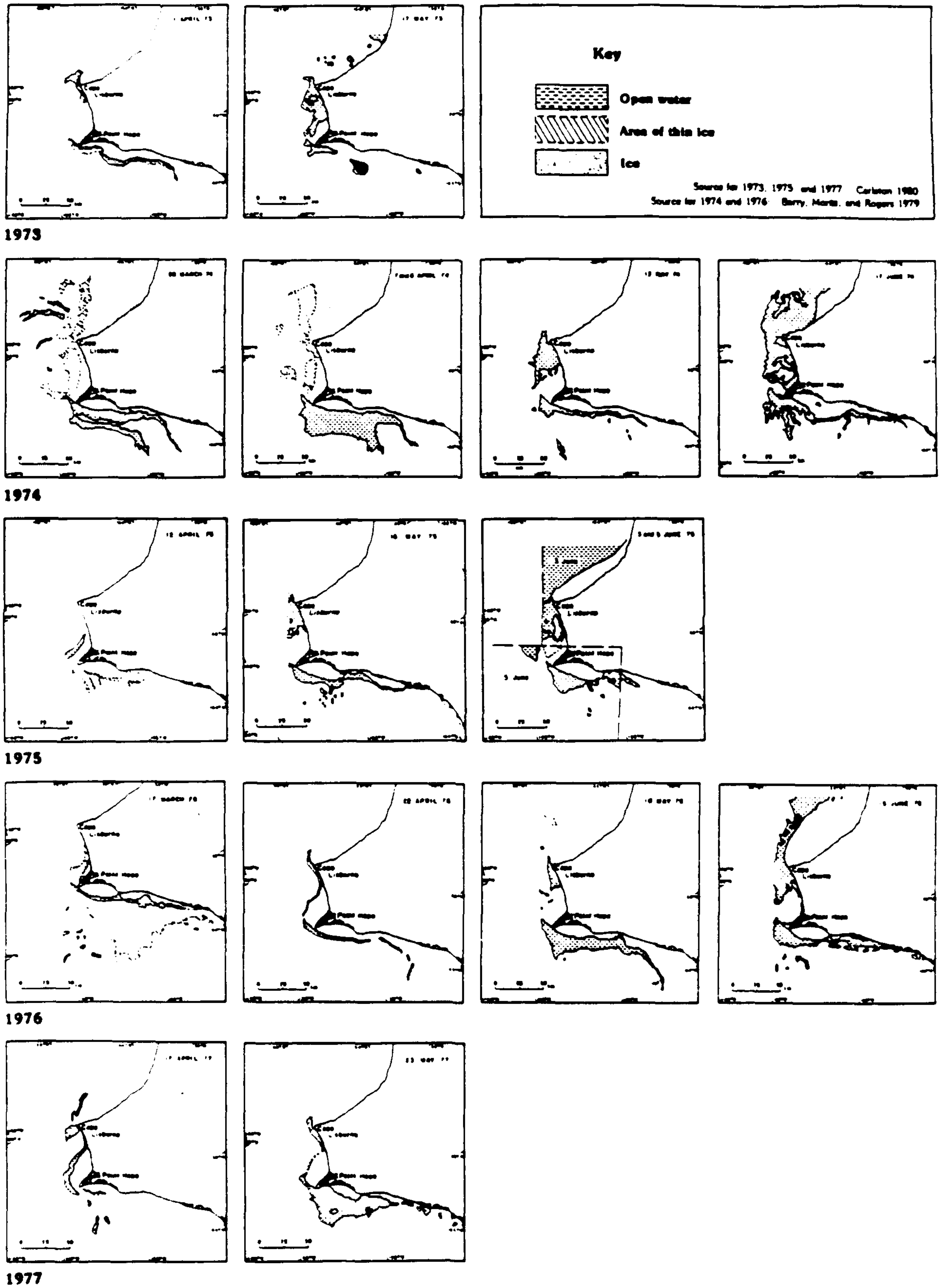


Figure 39

CHUKCHI SEA AVERAGE SEASONAL FAST ICE BOUNDARY

Chukchi Sea
Average Seasonal Fast Ice Boundary

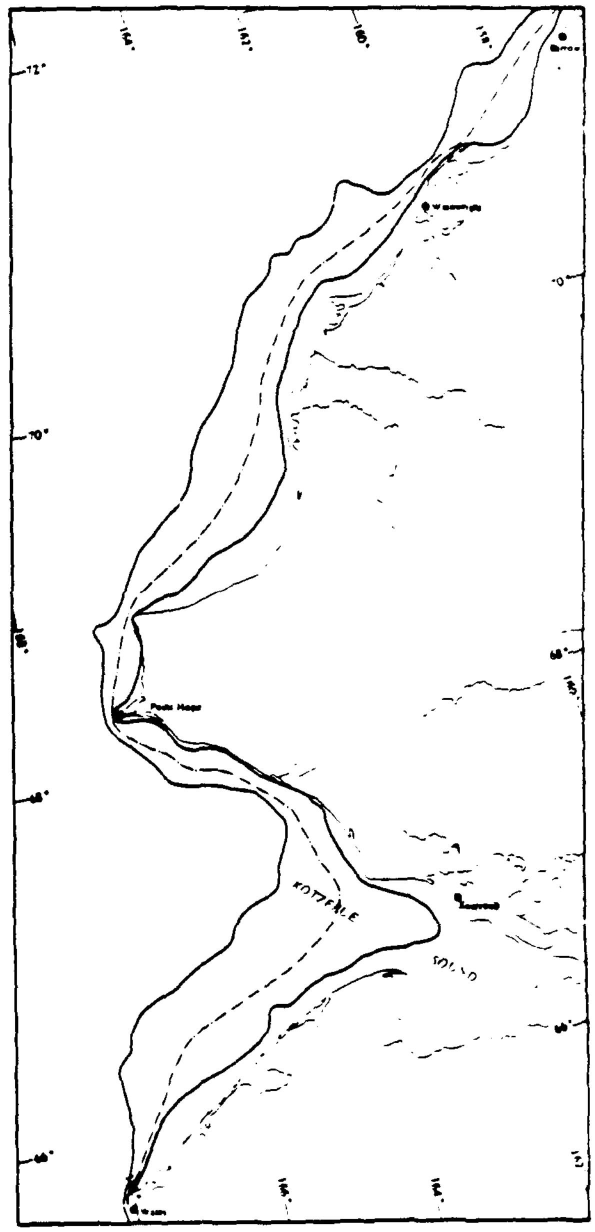
Key

- - - - - **Average**
——— **Maximum Deviation**

0 50 100 Nautical Miles

0 50 100 Kilometers

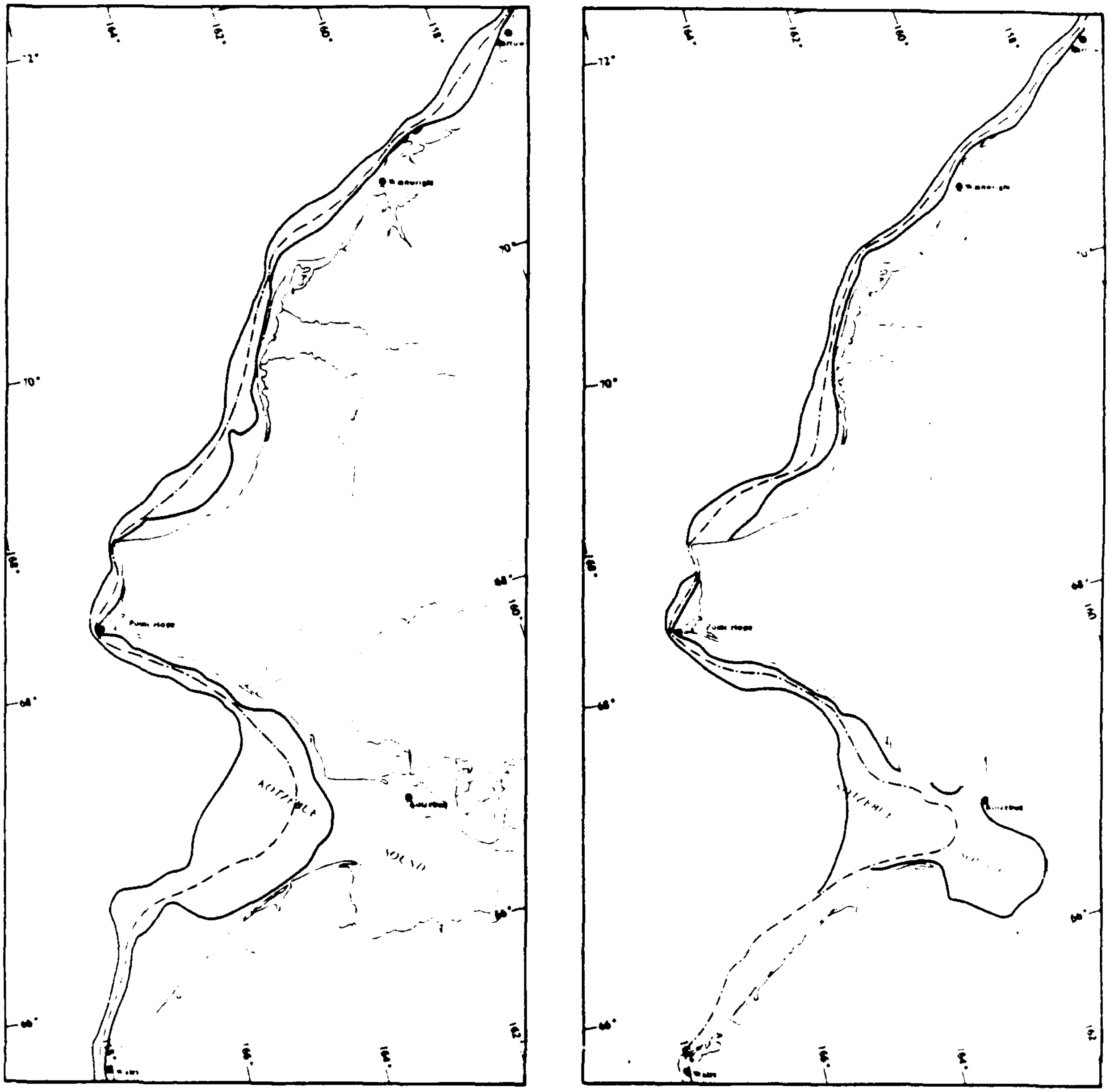
Synthesized from Stringer, Barrett, and Schreurs 1980



February-March

Figure 40a

CHUKCHI SEA AVERAGE SEASONAL FAST ICE BOUNDARY

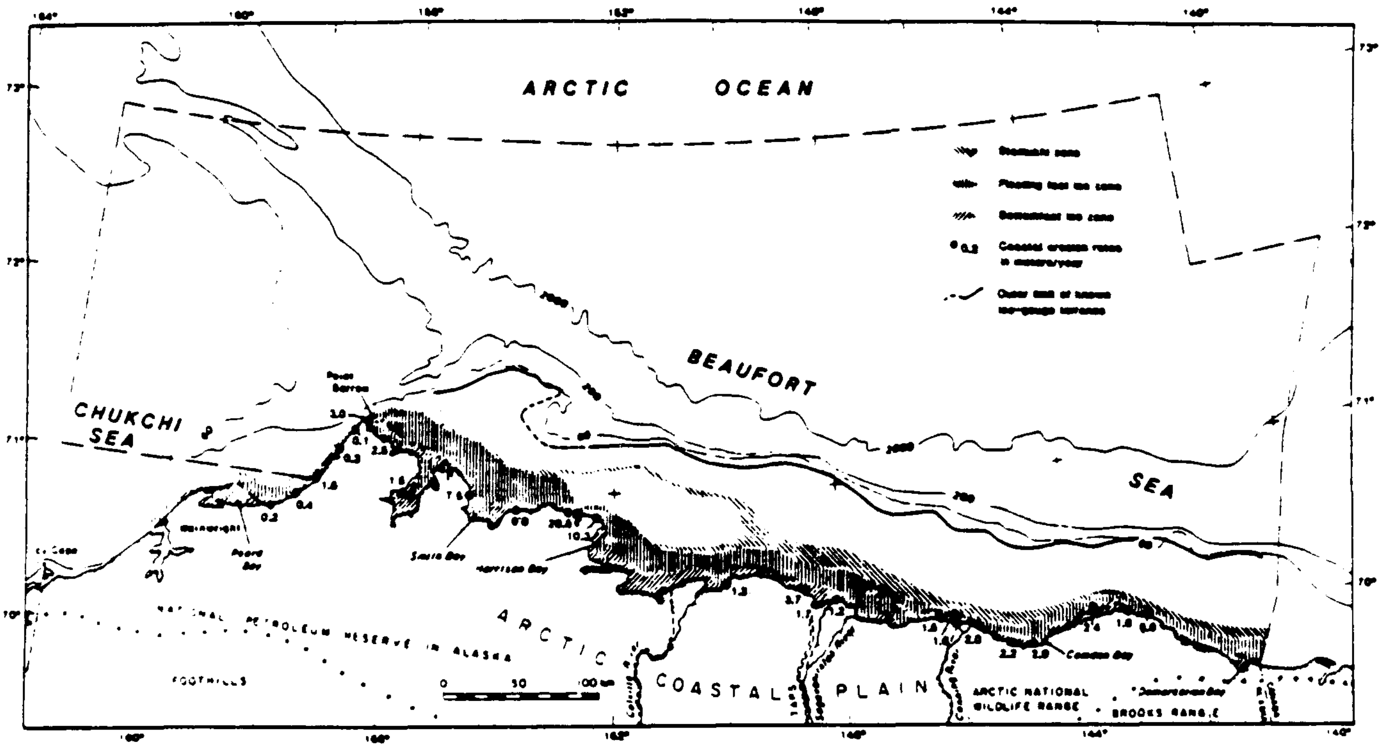


April-May

May-June

Figure 40b

NEARSHORE ICE



Example of nearshore ice zonation for Northeast Chukchi Sea and Beaufort Sea. (After Grantz et al. 1982).

Figure 41

FAST ICE AND SHEAR ZONES

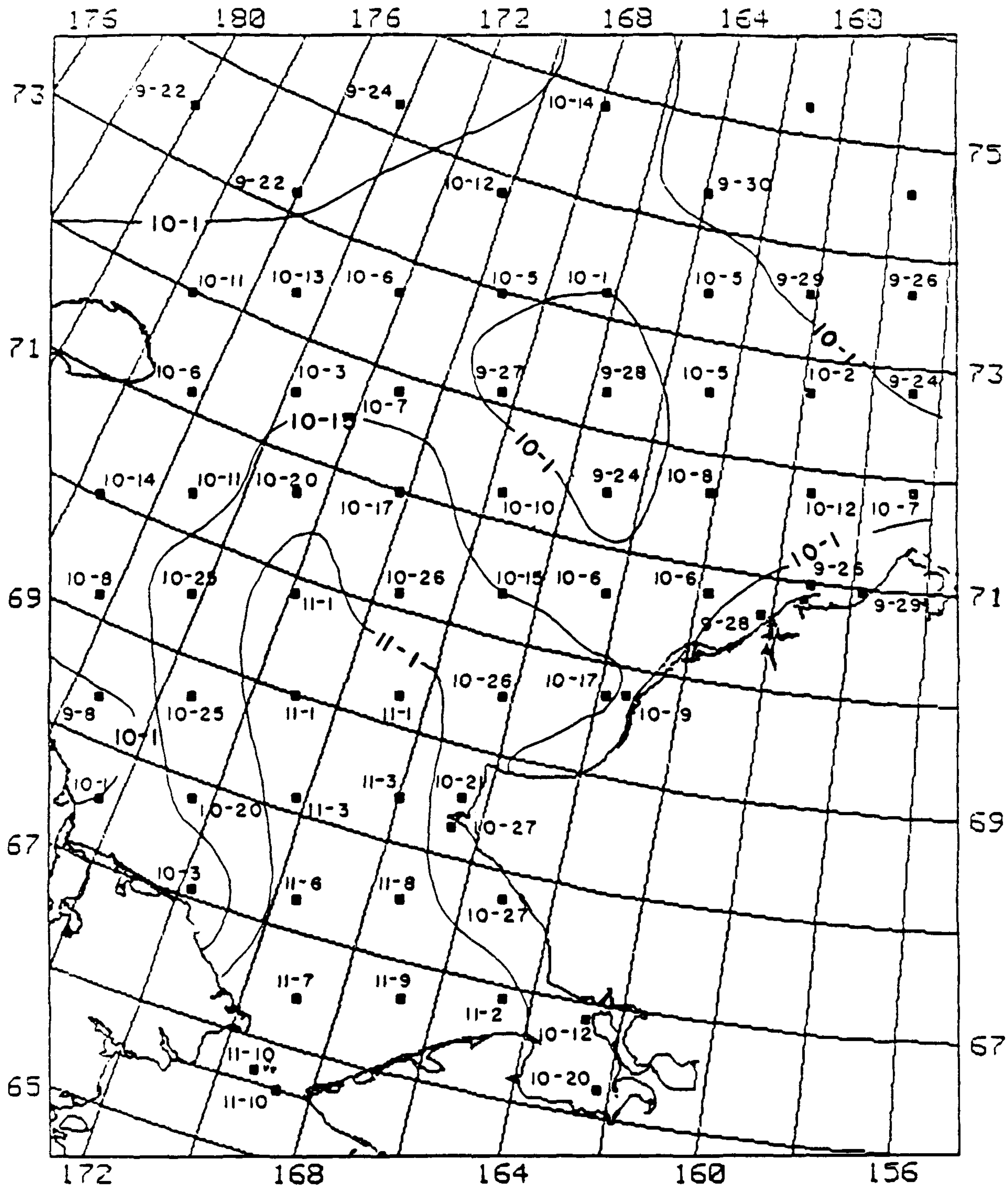
A common feature at the seaward boundary of the fast ice is an area of shear ridges. This feature is prominent along the Chukchi Sea coast northeast of Cape Lisburne, and north of the Seward Peninsula between Wales and Shishmaref. Deep gouges in the sea floor are common in this shear zone since these ridges are often grounded. In the Chukchi Sea this shear zone usually migrates seaward as the winter progresses. Gouges in the sea floor can also be caused by multi-year ice pieces in the north and by heavily hummocked ice pieces (floebergs) in all areas except the southern Bering Sea.

FREEZEUP/BREAKUP DATES

Building on the earlier work of LaBelle et al. (1983), Potocsky (1975), and the U.S. National Ocean Survey (1985), Stringer and Groves (1987), have analyzed twelve years of data on timing of ice freezeup and breakup. Figures 42 and 43 show the average and median dates, respectively, of freezeup at 67 stations in the Chukchi Sea and bi-weekly isopleths. Figures 44 and 45 provide similar information on ice breakup. Figures 46 and 47 show average and median ice-free water respectively. There is open water for 80-100 days beginning in August and continuing through the end of October. Figure 48 shows isopleths for the probability of ice recurrence for the study area.

This recent work of Stringer and Groves (1987) confirms the ice edge patterns found by Webster (1981) and also illustrates the influence of melt-back bays earlier suggested by Paquette and Bourke (1981). These melt-back bays are persistent features formed when a tongue of warmer Bering Sea water is channeled by the shallow Chukchi Sea bathymetry and the ice melts back continually at the ice edge. The five largest melt-back bay features are: (1) the Herald Canyon Bay between 170°W and 175°W; (2) the 168°W Bay; (3) the Alaskan Coastal Bay (the nearshore lead along the coast); (4) the Barrow Canyon Bay W to WNW of Point Barrow; and (5) the West Barrow canyon Bay for the bay suggested by Paquette and Bourke (1981) as formed by the branching of the Alaskan Coastal Current at 160°W along the western branch of Barrow Canyon. Over the season, the appearance of these five bays varies usually with only three of the bays present at the same time. The warmer currents involved in the formation of these five melt-back bays appear to be much more important in channeling the pattern of breakup than that of freezeup.

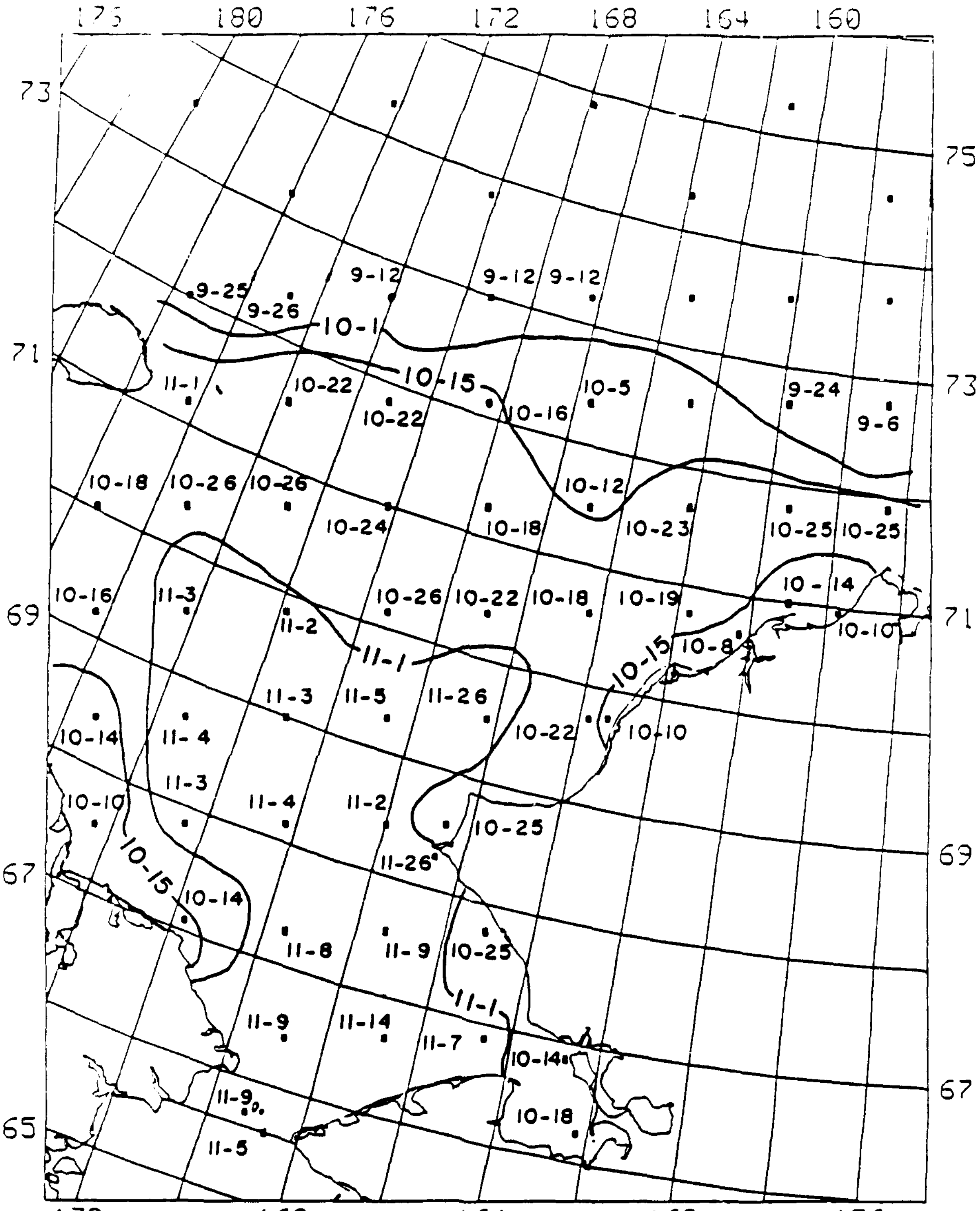
AVERAGE DATE OF FREEZEUP



Average date of Freezeup calculated at 67 stations in the Chukchi Sea. Freezeup is defined by the termination of the longest period of ice-free water. After Stringer and Groves (1987).

Figure 42

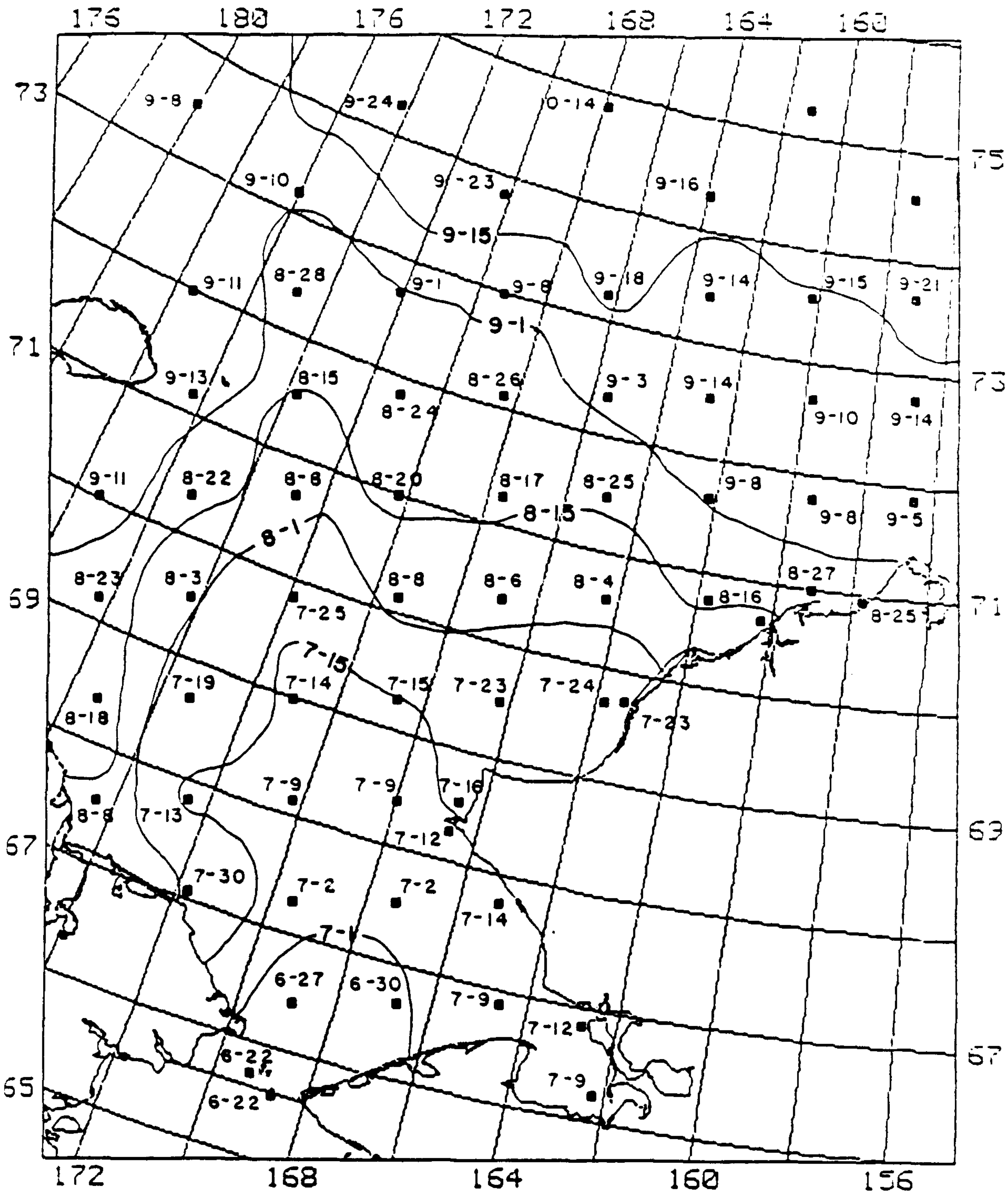
MEDIAN DATE OF FREEZEUP



Median date of Freezeup determined for 67 stations in the Chukchi Sea. Freezeup is defined by the termination of the longest period of ice-free water. After Stringer and Groves (1987).

Figure 43

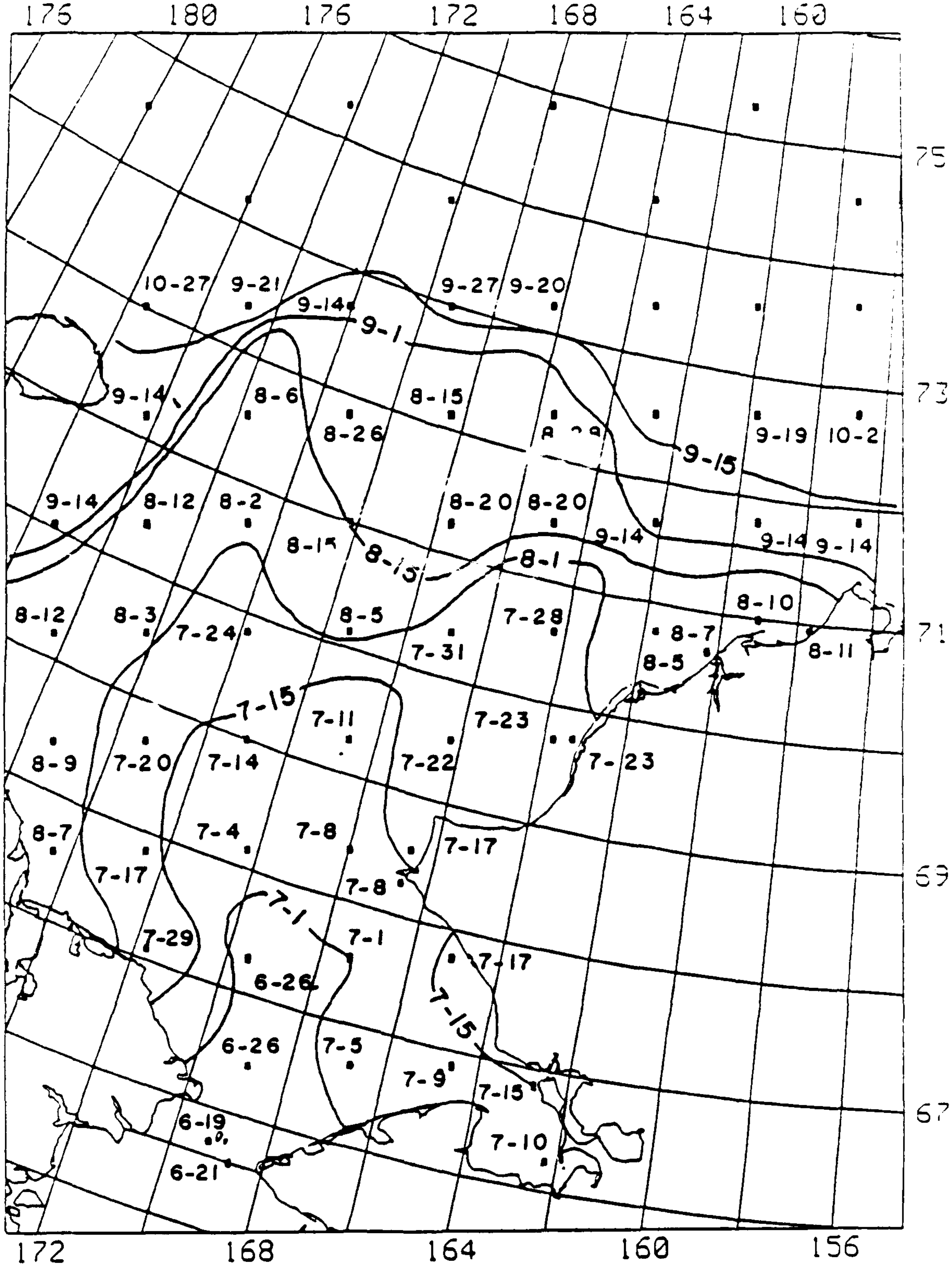
AVERAGE DATE OF BREAKUP



Average date of Breakup calculated at 67 stations in the Chukchi Sea. Breakup is defined as the beginning of the longest period of continuous ice-free water. After Stringer and Groves (1987).

Figure 44

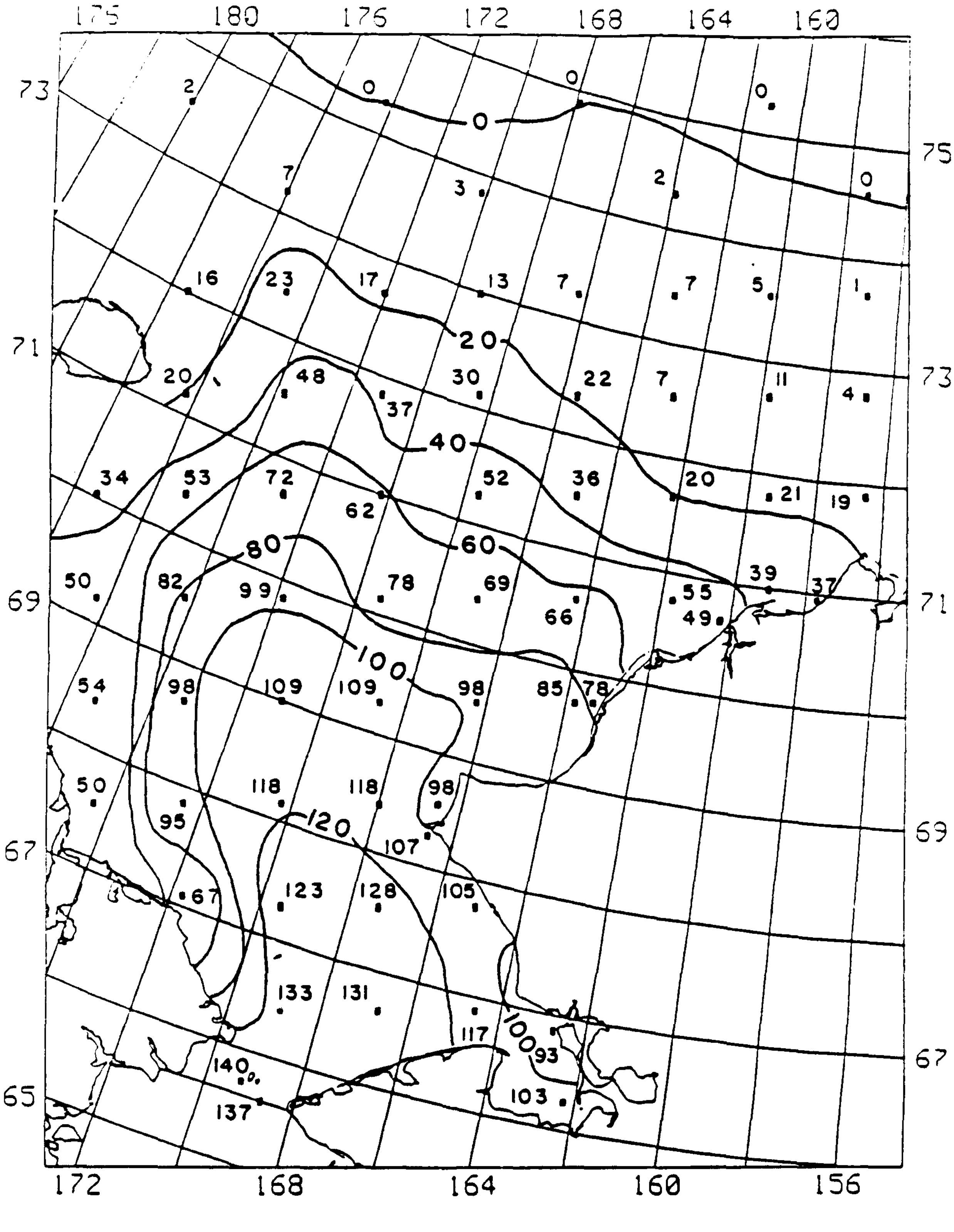
MEDIAN DATE OF BREAKUP



Median date of Breakup determined for 67 stations in the Chukchi Sea. Breakup is defined as the beginning of the longest period of continuous ice-free water. After Stringer and Groves (1987).

Figure 45

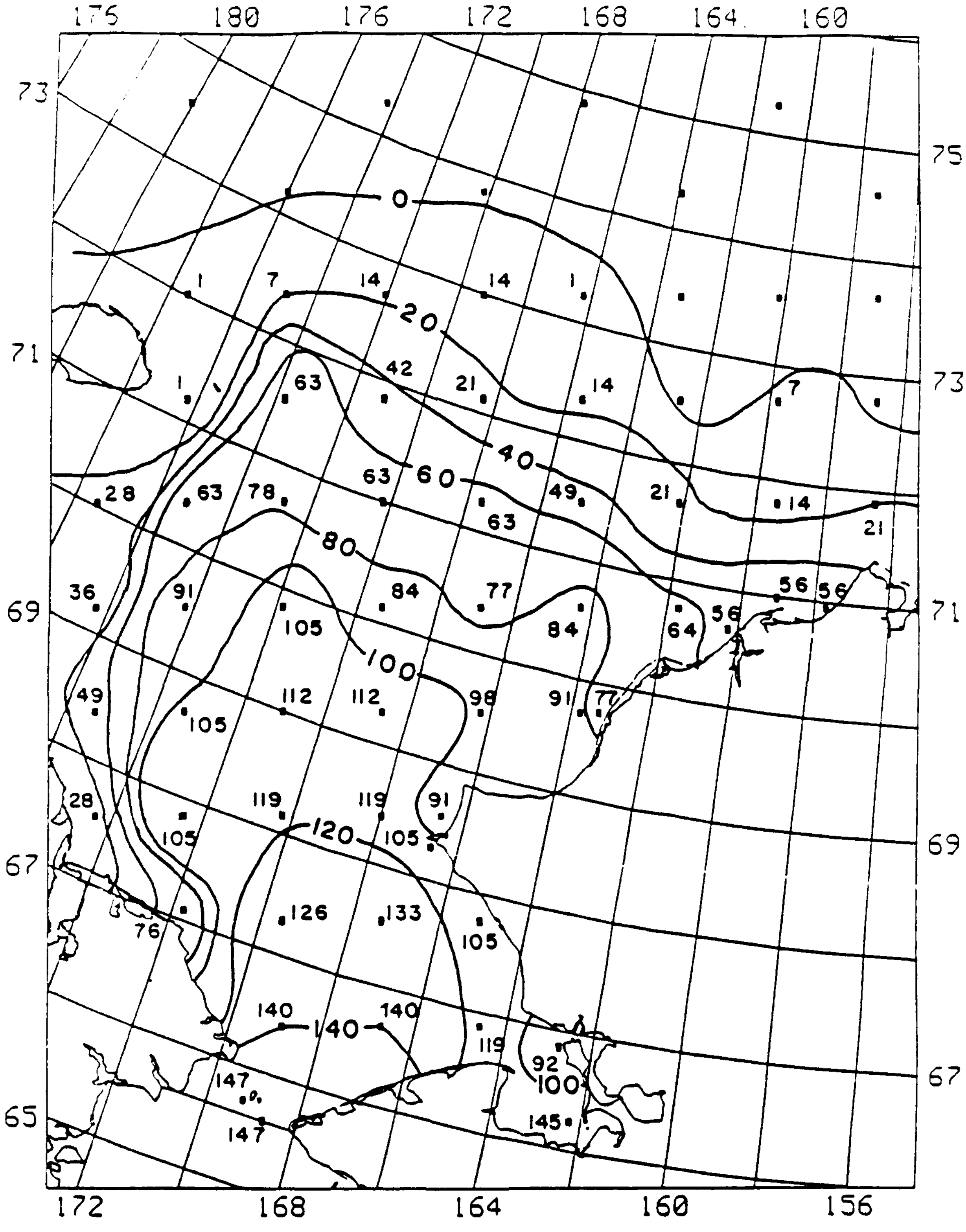
AVERAGE LENGTH OF ICE-FREE WATER (DAYS)



Average length in days of the longest period of continuous ice-free water calculated at 67 stations in the Chukchi Sea. After Stringer and Groves (1987).

Figure 46

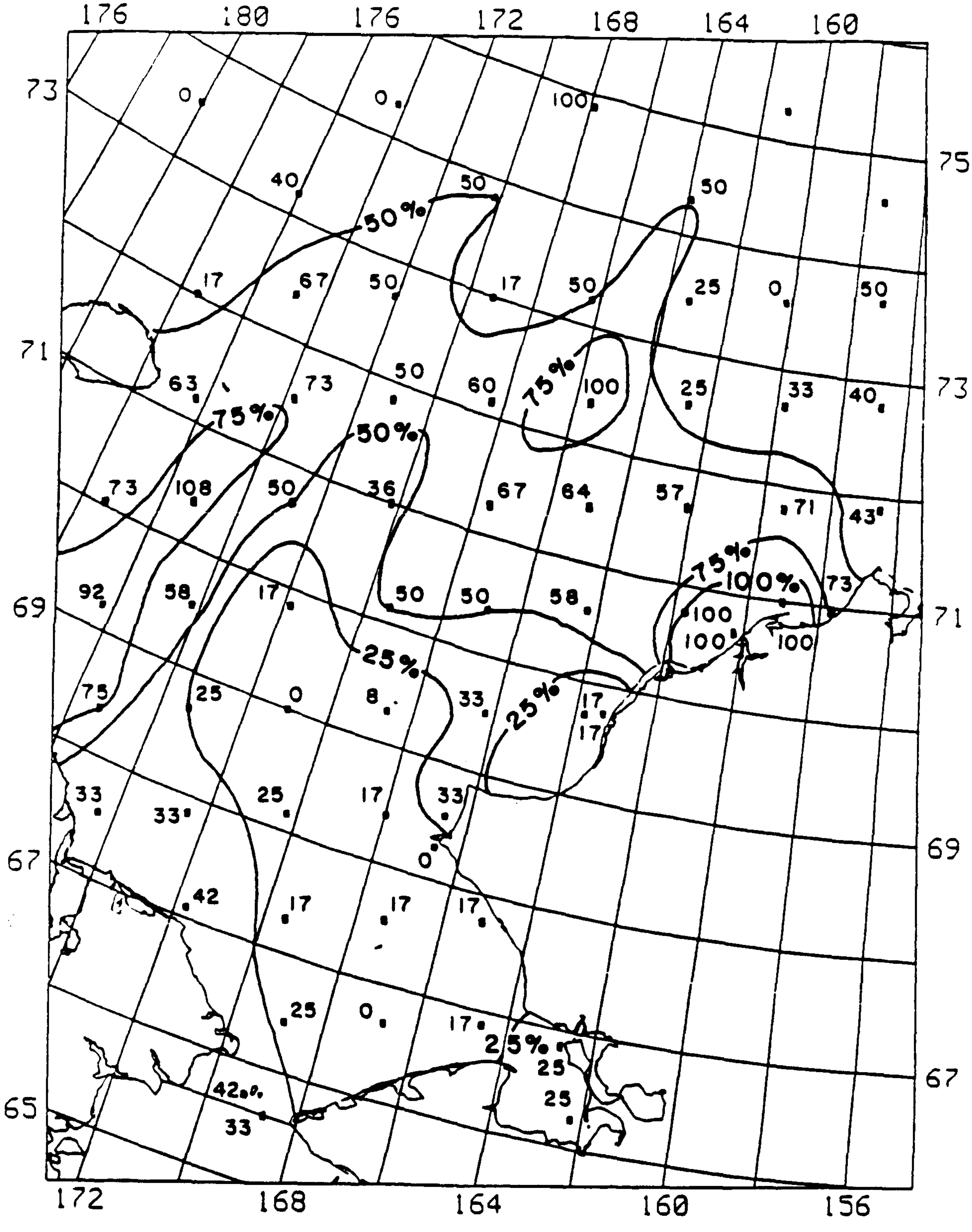
MEDIAN LENGTH OF ICE-FREE WATER (DAYS)



Median length in days of the longest period of continuous ice-free water determined for 67 stations in the Chukchi Sea. After Stringer and Groves (1987).

Figure 47

FREQUENCY OF ICE RECURRENCE



Percent frequency of ice recurrence at 67 stations in the Chukchi Sea. After Stringer and Groves (1987).

Figure 48

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